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Stateline Unit Resource Analysis
Step Two

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URA STEP 2 PHYSICAL PROFILE-CLIMATE
STATELINE VIRGIN VALLEY PLANNING UNITS

INTRODUCTION

Nevada lies just east and to the leeward side of the Sierra Nevada Range, a massive mountain barrier which has a marked influence on the climate of the State. One of the greatest contrasts in precipitation found within a short distance in the United States occurs between the western slopes of the Sierras and the valleys located easterly of this range. The prevailing winds are from the west, and as moist air associated with storms from the Pacific Ocean ascends the western slopes of the Sierras, a large portion of the original moisture falls as precipitation. As the air descends on the eastern slope, it is warmed and little precipitation occurs. Because of this mountain barrier, the low lands of Southern Nevada are largely desert areas. Because of its varied and rugged topography, Nevada has wide local variations of temperature and rainfall. The most striking climate features are bright sunshine, small annual precipitation in the valleys and deserts, larger amounts of precipitation in the mountains, dryness of air and extremely large daily ranges of temperature.

PRECIPITATION

Precipitation levels for the planning unit are quite low for the lower elevations, averaging between four and eight inches per year. Increases in precipitation occur as one climbs in elevation and at higher elevations, this may amount to as much as 20 inches per year, mostly falling as snow. Most precipitation falls in the winter months occurring as rainfall in

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the lower elevations and snow in the higher mountainous areas. Summer rainfall also occurs, generally in the form of intense convectional type thundershowers.

Because of the low rates of precipitation in the desert areas, the vegetative cover is very meager, thus limited amounts of feed are produced that can be utilized by wildlife or livestock, except during the wetter years, when the deserts litterly "bloom".

However, because of the overall lack of precipitation there is generally little water from this source that can be made available for use, and water is often the limiting factor when consideration is being given to undertake a particular resource project.

EFFECTS OF SNOWFALL ON RESOURCE MANAGEMENT

For a majority of the planning units, there is little or no snow pack, as it generally melts within a relatively short period of time. However, at the higher elevations, snow remains for longer periods of time, and the runoff resulting from snowmelt provides the main source of water for streamflow. Flooding, because of runoff from snowmelt, is quite rare in the planning units, because of the limited amounts of precipitation occurring.

HUMIDITY

Relative humidity for the area is generally low, with daily fluctuations in January, the most humid month, averaging between 34 and 61 percent, and in July, the driest month, between 10 and 25 percent. The low humidity and abundant sunshine produce rapid evaporation, often exceeding

80 inches annually, (see Appendix IV). Because of the resulting high evaporation, much of the precipitation does not have the opportunity to enter the groundwater system, but instead is lost to the atmosphere.

TEMPERATURES

As can be seen from Appendix III, the January mean minimum temperatures range from 16 in the higher elevations to 36 degrees along the south-eastern portion of the planning unit. The mean maximum temperatures are about 44 in the upper elevations to 56 degrees in the southern part of the planning unit. For July, the mean minimum temperatures range from 52 at the highest elevations to 76 degrees at the southern end of the state while the maximum temperatures are 80 and 104 degrees at the same respective locations.

For the planning units, the summers are long and hot, and the winters short and mild. There is relatively strong insulation of heat during the day and rapid nightime cooling, thus there are wide ranges in daily temperatures. However, because of the low relative humidity normally experienced, the higher temperatures are less disagreeable than they would be if found in more humid climates. Because of the climate in the area, many people have found the living to be quite healthful, thus this factor is an added inducement to individuals contemplating moving to Las Vegas or other areas within the planning units. The temperatures, as such, have little effect on the physical resources found in the area.

AIR MOVEMENT PATTERNS

Winds associated with major storms are strongest during late winter to early summer and accompany the Pacific frontal and continental cyclone systems. Winds during this period have average speeds between 13 to 16 miles per hour, while during the remainder of the year they generally range between four and six miles per hour. Wind gusts in excess of 50 miles per hour may accompany summer thundershowers. (See Appendix I for wind direction charts.)

All of southern Nevada is susceptible to air inversions because of the climatic and topographical features that are found in the area. The area is within the Las Vegas sub airshed which is part of a larger airshed covering Southern Nevada, southwest Utah and Northwest Arizona. The area covering the Las Vegas Valley and other outlying areas has an average inversion occurrence of 84 percent as computed in days per year. Such conditions exist on the average of about 3,600 hours per year with a surface inversion height of 700 feet or less about 50 percent of the time. Other areas within the planning unit have not been studied in sufficient detail to indicate specific inversion location; however, it can be expected that many of the other valleys present would have inversion rates similar to that data presented below which shows the inversion occurrence in the Las Vegas valley.

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DISTRICT HEALTH DEPARTMENT, CLARK COUNTY
Air Pollution Control Division

SURFACE INVERSION OCCURRENCE
October 1964 - September 1966, Incl.
Las Vegas, Nevada

By Month

Month	Occurrence % Days
January	87
February	80
March	85
April	79
May	74
June	90
July	85
August	88
September	86
October	92
November	86
December	83
All Months	84

NOTE: Computed from meteorological soundings furnished by U.S. Weather Bureau Station, McCarran Airport, Las Vegas, Nevada

By Height

Inversion Thickness, Ft.	Occurrence % Days
200	0.3
300	21.2
400	7.5
500	4.5
600	5.4
700	6.5
800	7.4
900	5.3
1000	4.6
1100	5.2
1200	3.9
1300	1.5
1400	2.8
1500	1.0
1600	1.7
1700	1.5
1800	1.0
1900	0.7
2000	0.1
over 2000	
1500 & less	

CLARK COUNTY HEALTH DISTRICT
Air Pollution Control Division

SULFATE VISIBILITY OCCURRENCES
October 1964 - September 1965, Incl.
Las Vegas, Nevada

By Month

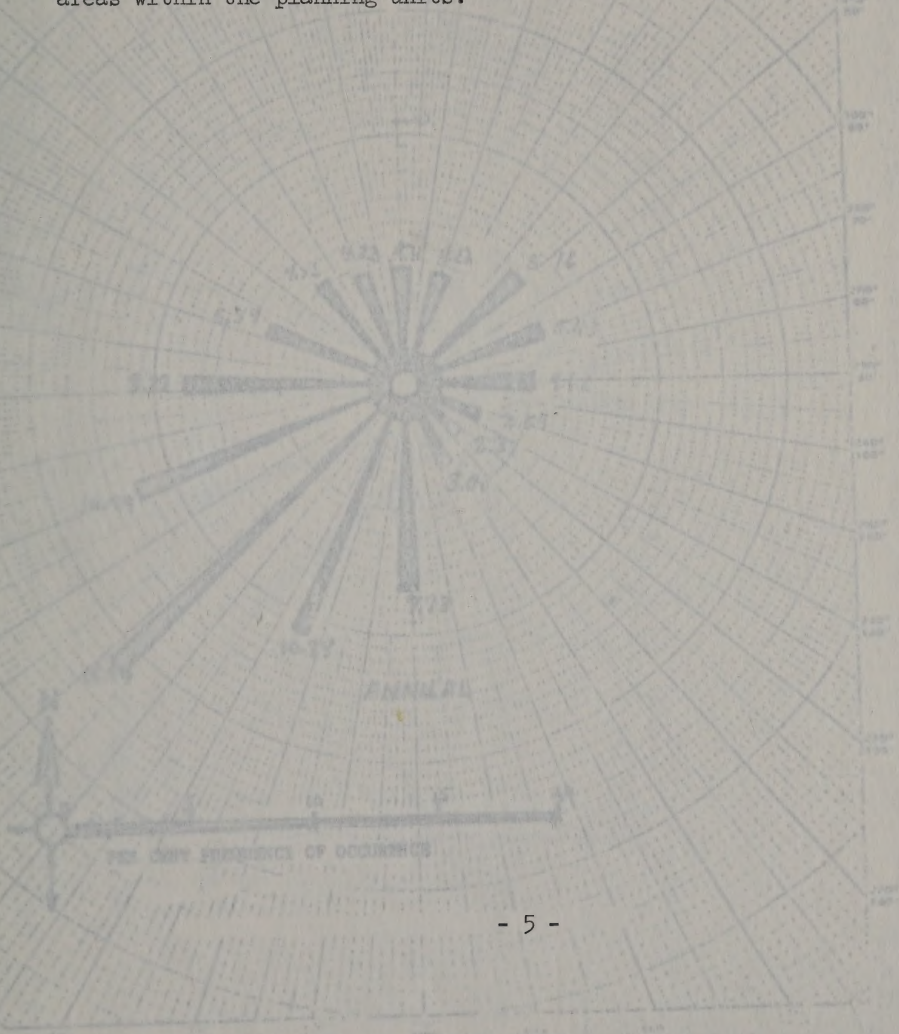
Month	Occurrence % Days	Inversion Thickness, Ft.	Occurrence % Days
January	87	200	0.3
February	80	300	21.2
March	85	400	7.5
April	79	500	4.5
May	74	600	5.4
June	90	700	6.5
July	85	800	7.4
August	88	900	5.3
September	86	1000	4.6
October	92	1100	5.2
November	86	1200	3.9
December	83	1300	1.5
All Months	84	1400	2.8
		1500	1.0
		1600	1.7
		1700	1.5
NOTE: Computed from meteorological		1800	1.0
soundings furnished by U.S. Weather		1900	0.7
Bureau Station, McCarran Airport,		2000	0.1
Las Vegas, Nevada		over 2000	

By Height

1500 & Less

FROST FREE GROWING SEASON

The growing season is generally over 200 days except in the higher elevations. Thus, there is ample time for the production of crops. However, because of the limitations of water, there are few agricultural areas within the planning units.



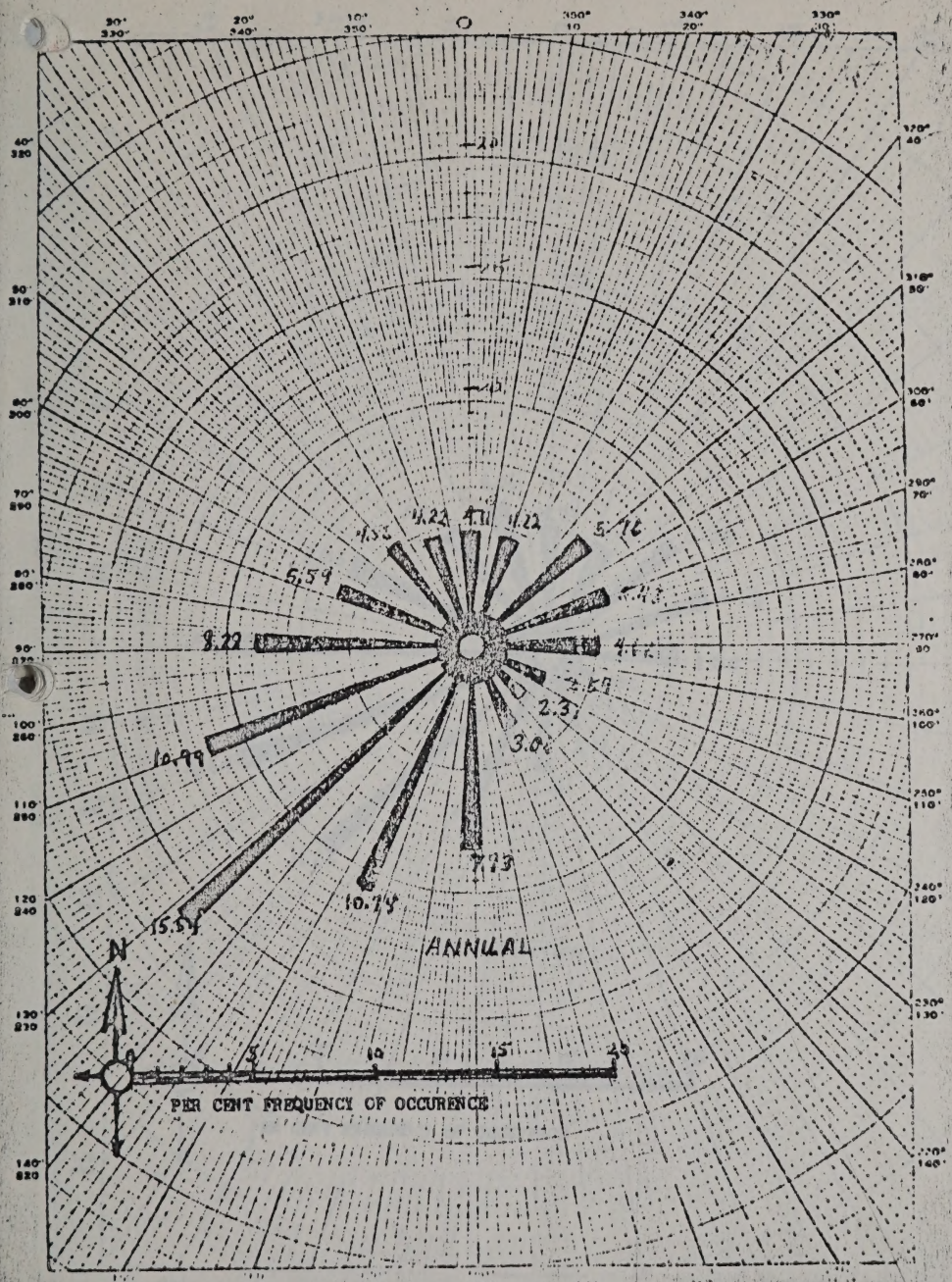
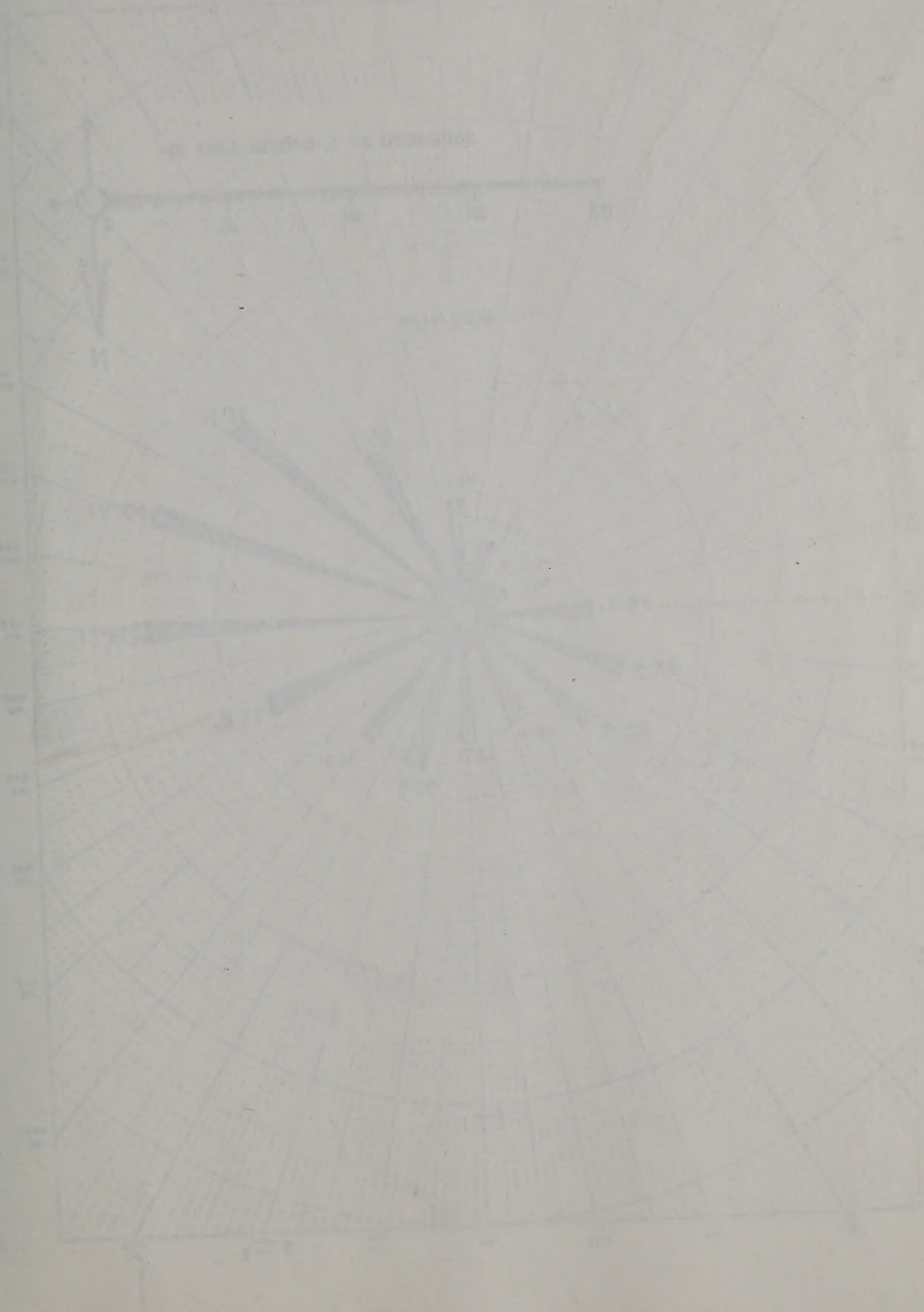


FIGURE 12. PER CENT FREQUENCY OF WIND DIRECTION, ANNUAL



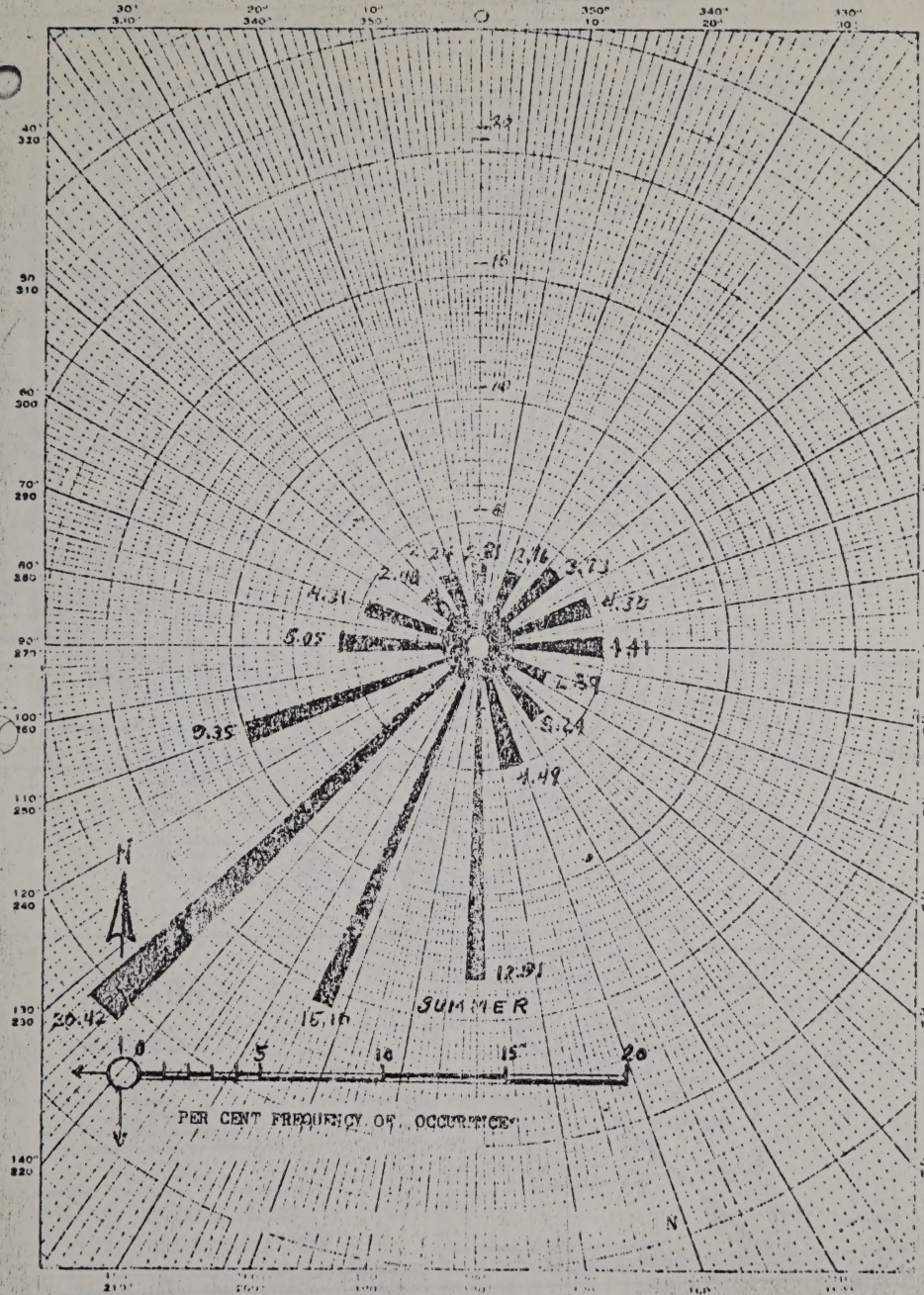
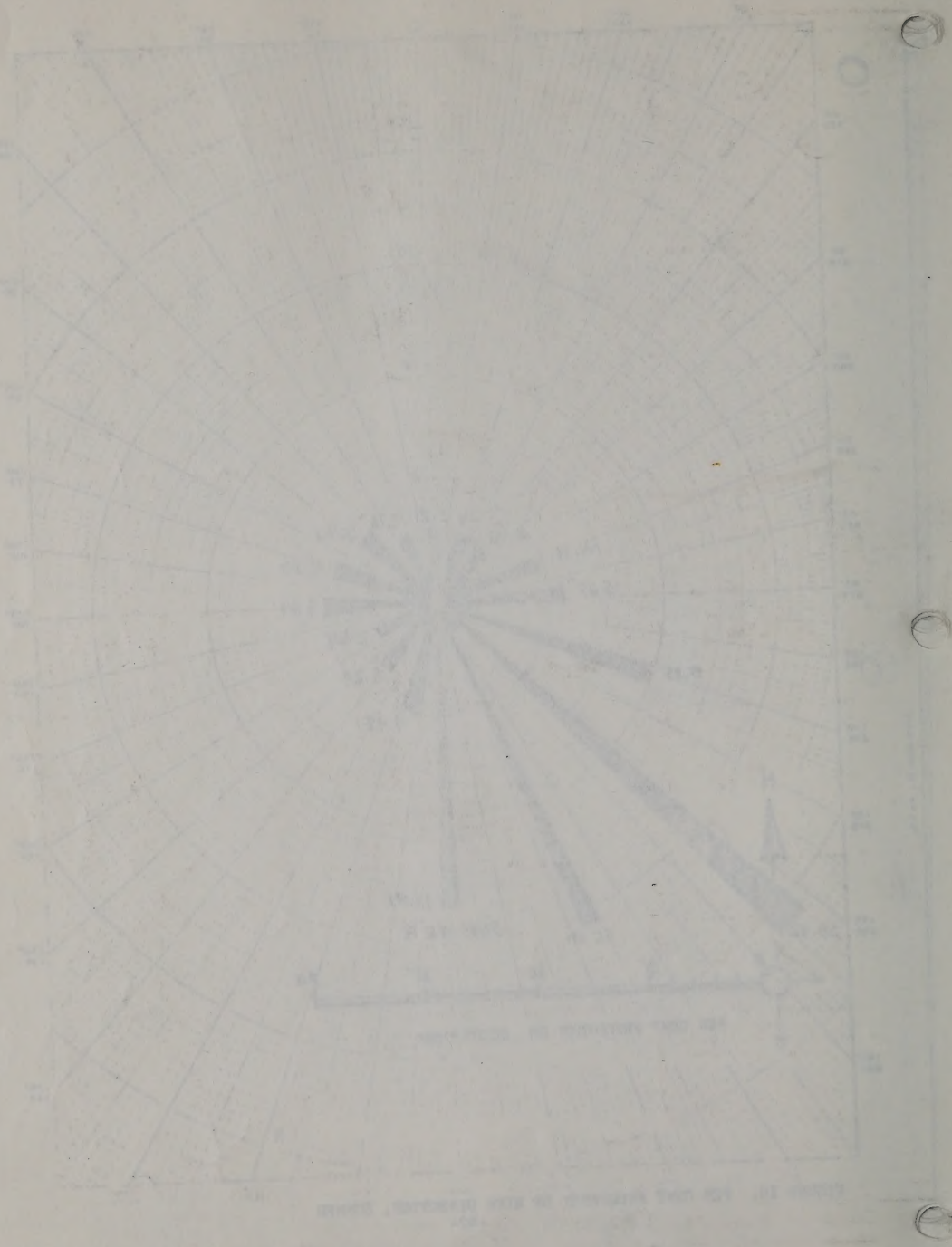
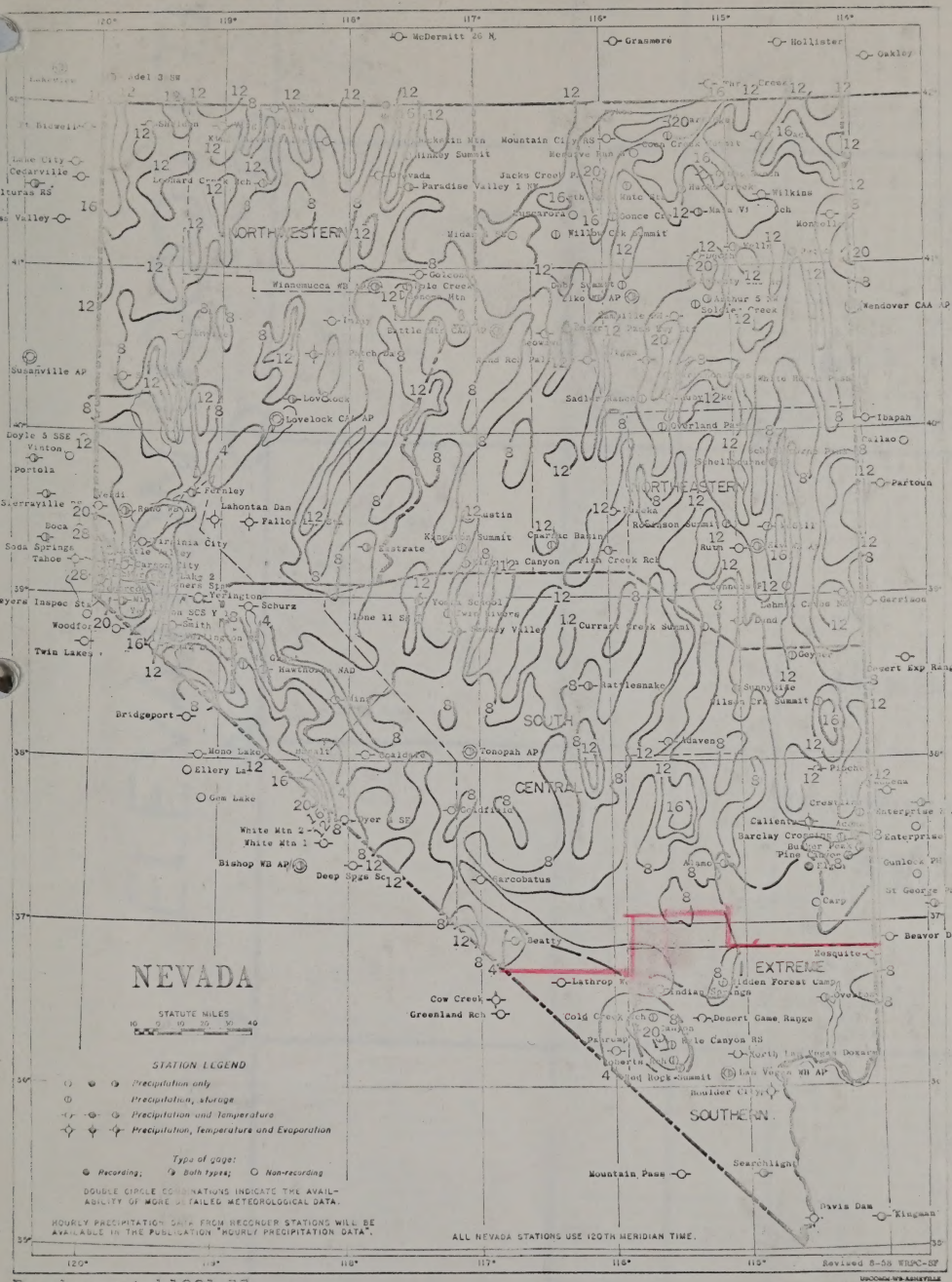


FIGURE 10. PER CENT FREQUENCY OF WIND DIRECTION, SUMMER

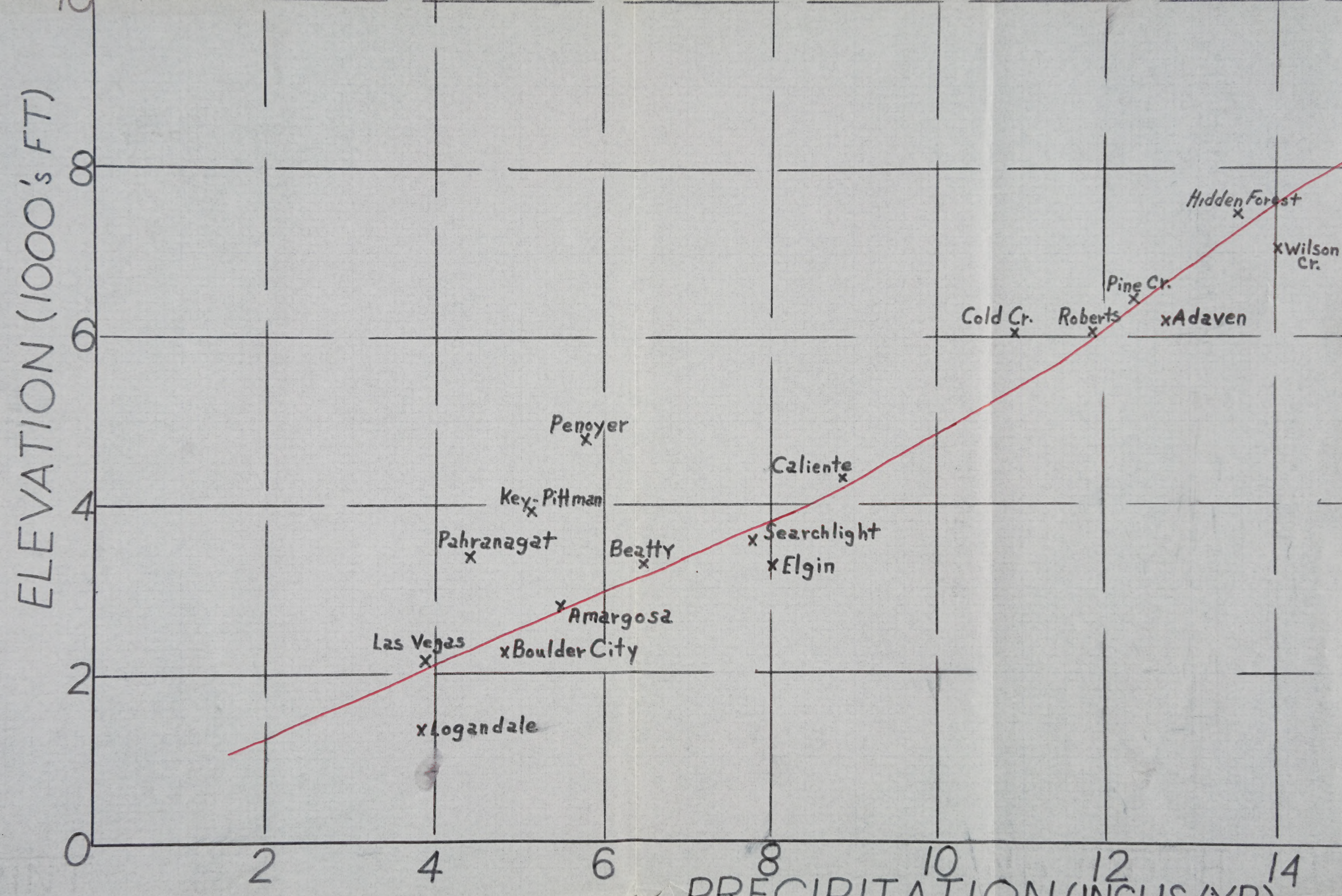


Mean Annual Precipitation, Inches



Based on period 1931-55

Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.


ELEVATION (1000's FT)
0
2
4
6
8
2
4
6
8
10
12
14
PRECIPITATION (INCHS/YR)
Hidden Forest
Wilson Cr.
Pine Cr.
Cold Cr.
Roberts
Adaven
Penoyer
Caliente
Key-Pittman
Pahranagat
Beatty
Searchlight
Elgin
Amargosa
Las Vegas
Boulder City
Logandale

ELEVATION (1000's FT)

8

6

4

2

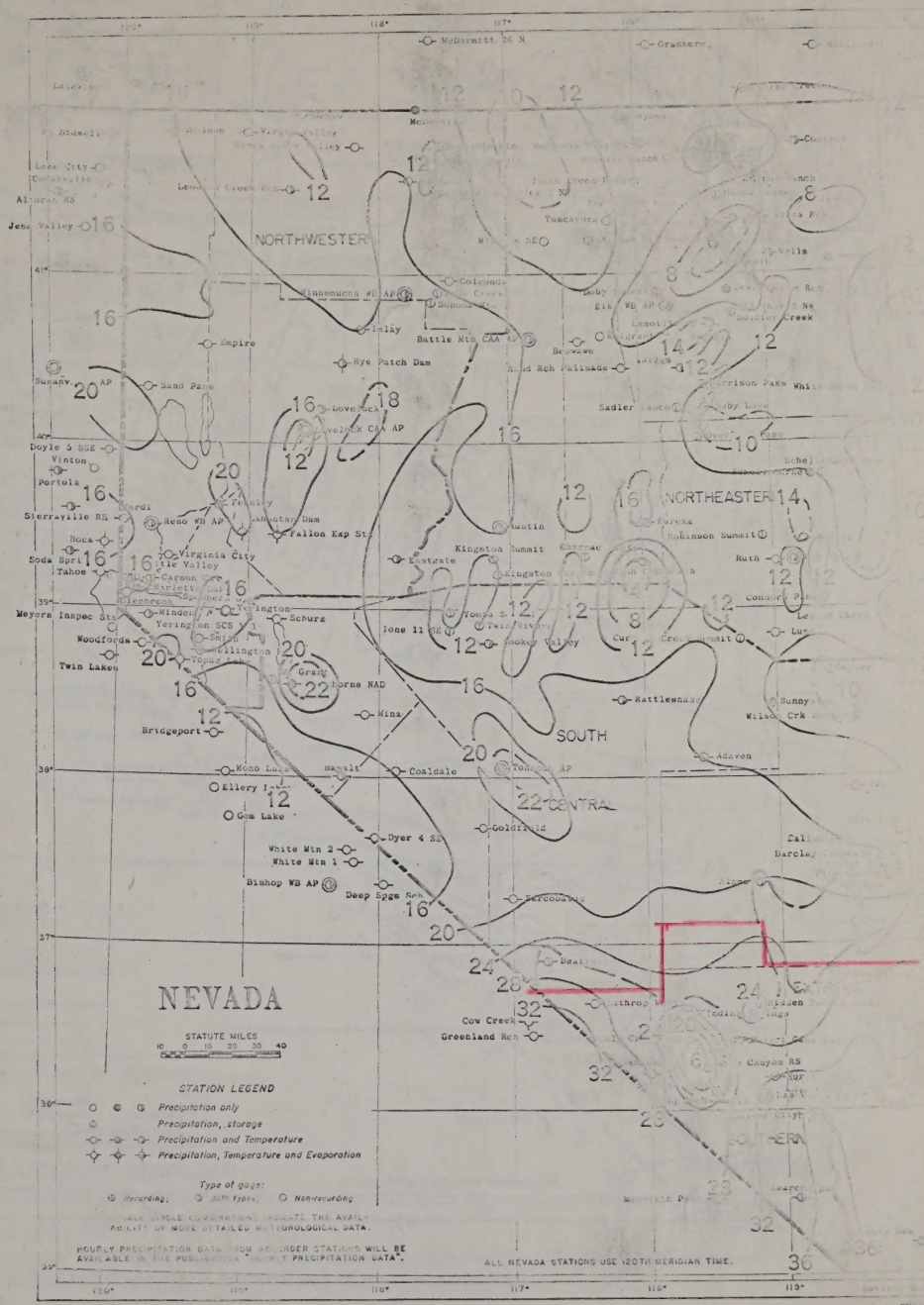
0

Las Vegas

Pahrump

Appendix III

Mean Minimum Temperature (°F.) January



Based on period 1931-52

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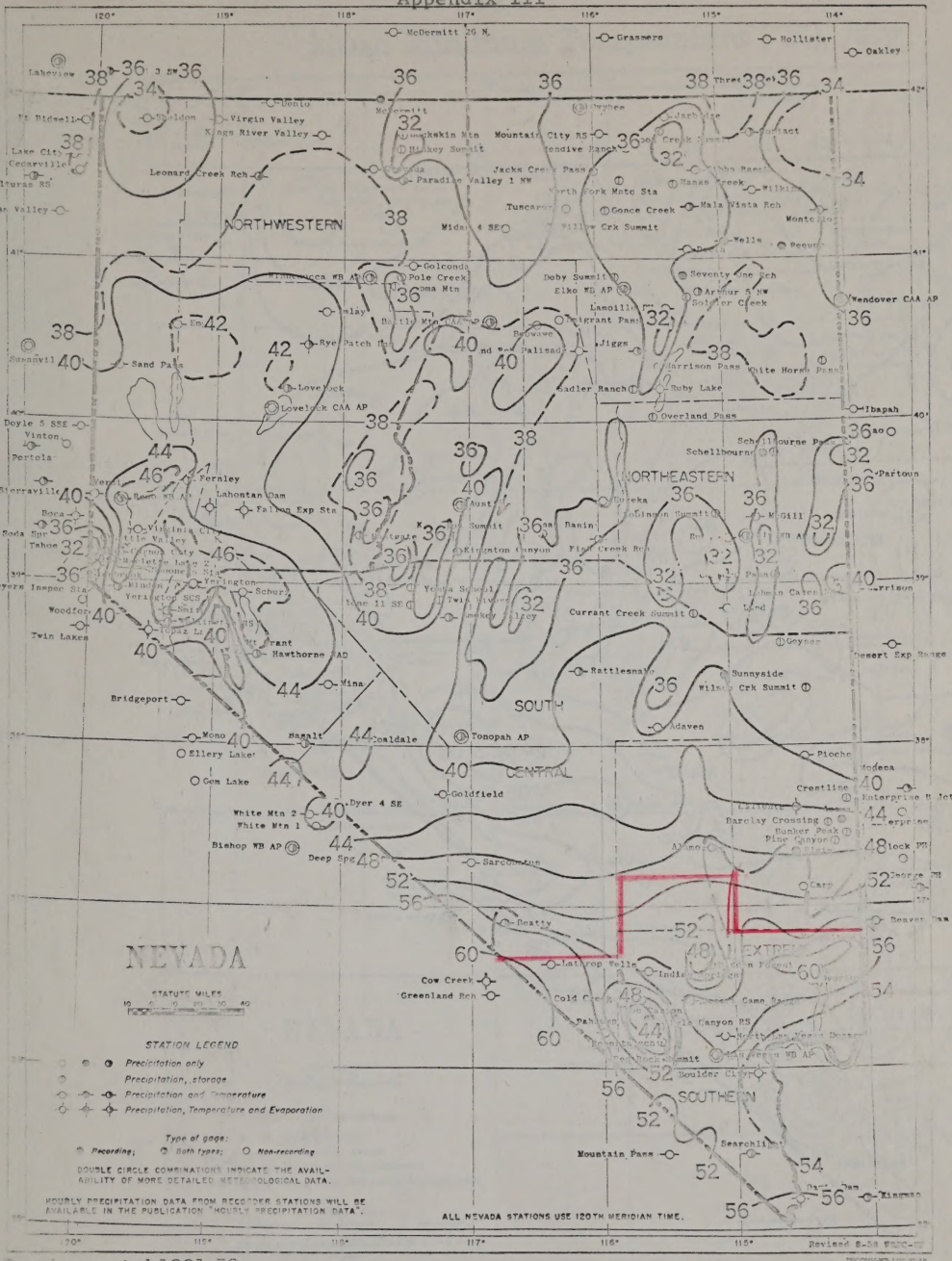
Mean Maximum Temperature (°F.), January

Appendix III



Based on period 1931-52

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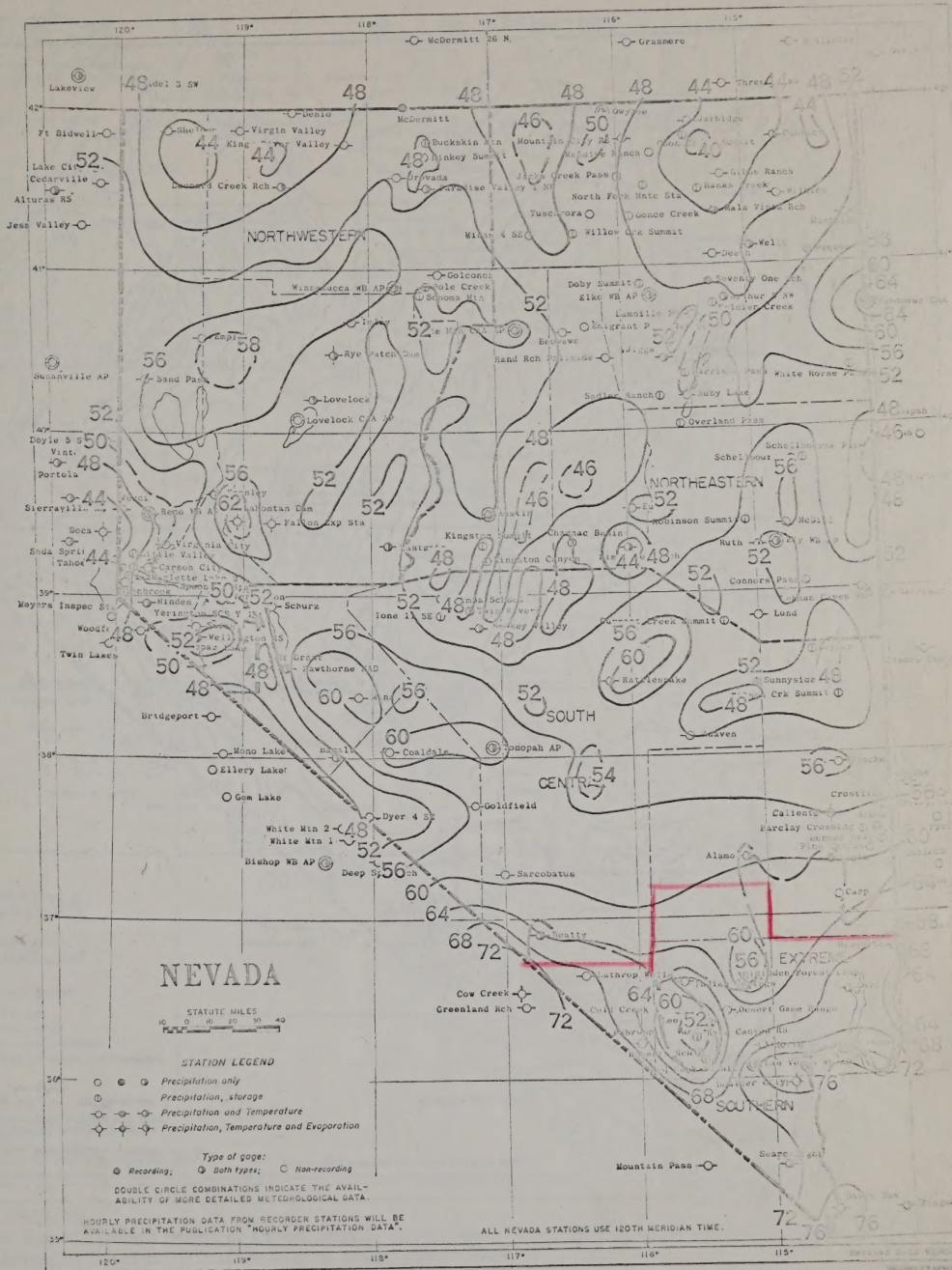
Mean Minimum Temperature (°F.), July



Based on period 1931-52

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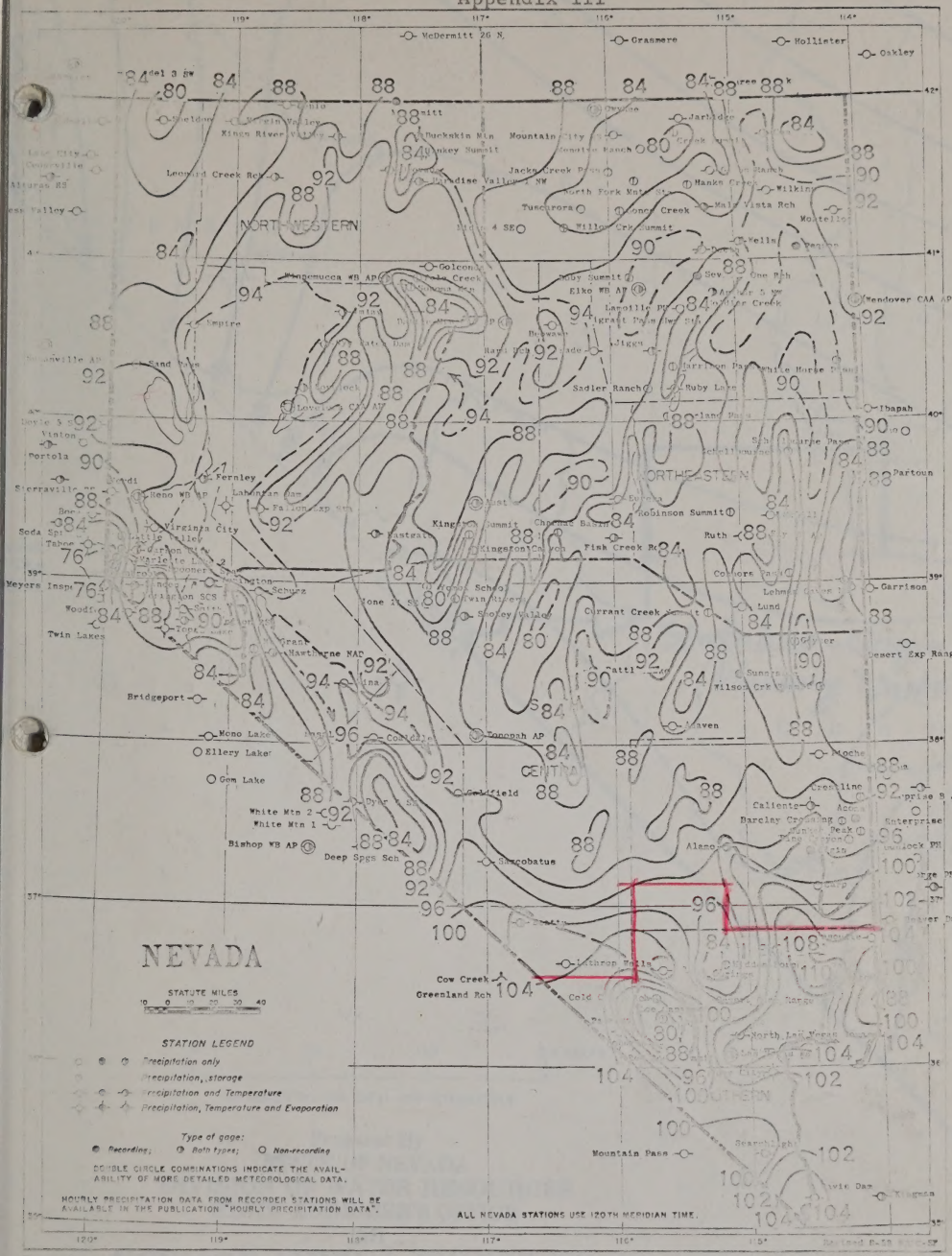
Mean Maximum Temperature (°F.), July

Appendix III



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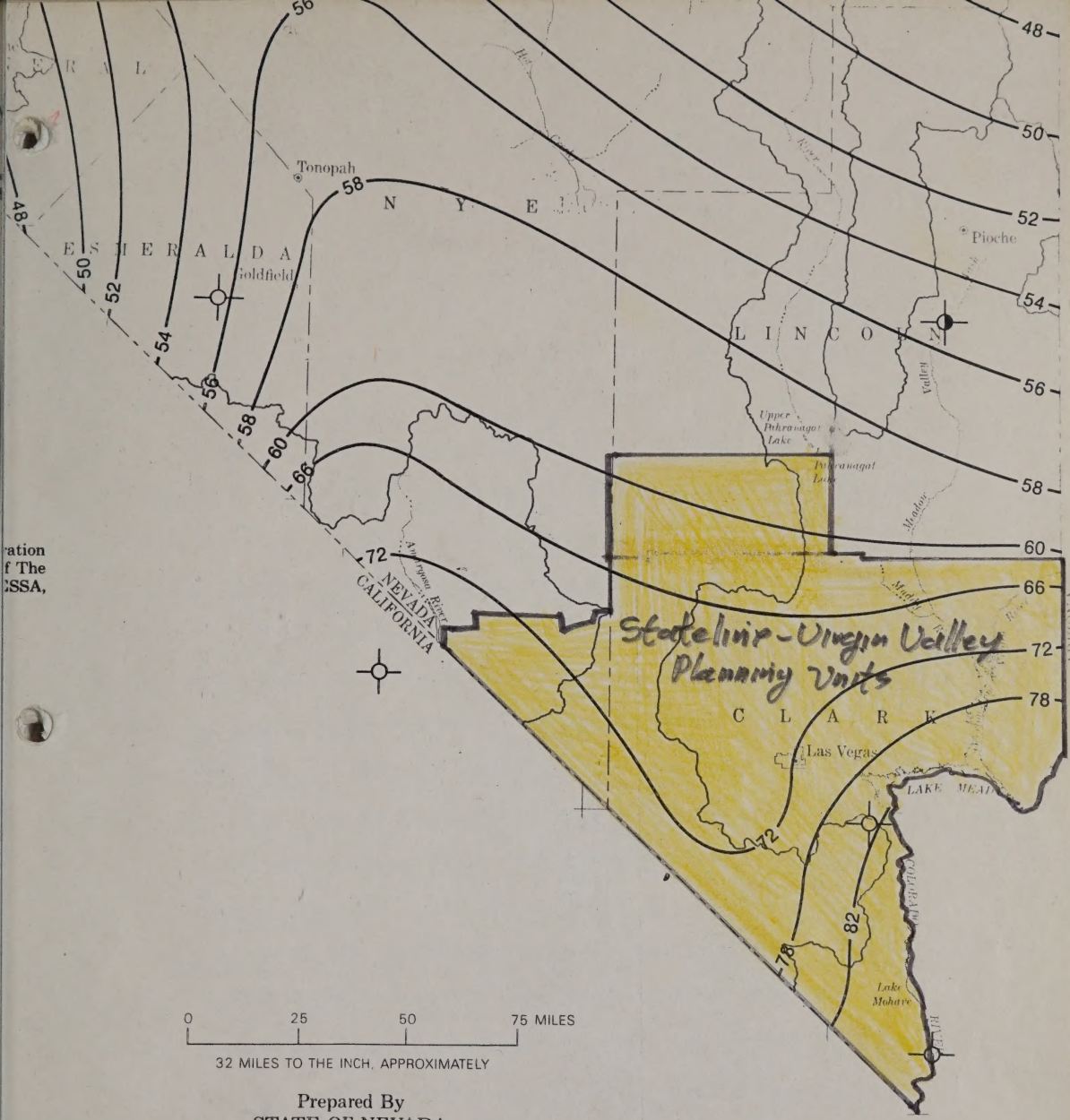

0 25 50 75 MILES

32 MILES TO THE INCH, APPROXIMATELY

Prepared By
STATE OF NEVADA
DIVISION OF WATER RESOURCES
STATE ENGINEER'S OFFICE
1971

AVERAGE ANNUAL EVAPORATION

Edited by B. R. Scott

Cartography by L. M. Roa
with coop
Branch of
U.S.G.S.,

Topography - Stateline Planning Unit (0504)

The Stateline Planning Unit covers parts of Clark County and Nye County, Nevada. It is part of the Basin and Range Physiographic Province, and is characterized by elongate north-south trend mountain ranges that are seperated by alluvial-filled valleys (see figures #1 and #2).

The most easterly mountains occur along the western bank of the Colorado River and include the Sunrise, River, Eldorado, Opal and Newberry Mountains. A second series of mountains occurs in the central portion of Clark County and include the McCullough, Highland Spring, Lucy Grey, and Castle Mountains. The Castle Mountains continue southward into California. In the western portion of Clark County are the Birdspring and Spring Mountains. The Spring Mountains are the most prominent peaks in the area. Mount Charleston reaches an altitude of 11,918 feet and is the third highest peak in Nevada. It is the highest in the Stateline Planning Unit. The Spring Mountains extend westward into southern Nye County. To the northwest of this extension of the Spring Mountains are the Striped Hills and Specter Mountains. Both of these straddle the northern boundary of the planning unit (see figure #2). A small range of low, unnamed hills and peaks occur to the west of the Spring Mountains in Nye County. Other than these, no other mountains occur in the area.

To the north of the planning unit a series of ranges occur including the Arrow Canyon, Las Vegas, Sheep, Pintwater, Spotted, Skull and Yucca

Robert J. Sulenski
January 15, 1973

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Mountains. These mountains are either in the Desert Game Range, the Nellis Air Force Bombing Range or the A.E.C Test Site. To the northeast of the planning unit, the Black and Muddy Mountains occur. These are part of the Virgin Valley Planning Unit (0502).

The major valleys in the planning unit are the Colorado River Valley, Las Vegas Valley, Piute Valley, Eldorado Valley and Pahrump Valley (see figures #1 and #2). Pahrump Valley enters the southwestern portion of Clark County from Nye County and extends into California. The Las Vegas Valley extends across the planning unit from Mercury Valley in Nye County eastward across Clark County to Boulder City. There it joins the Eldorado Valley which swings southward past Searchlight and on into Piute Valley.

The Colorado River Valley forms the eastern boundary of the planning unit from Lake Mead south to the southernmost tip of Nevada. Hoover Dam and Davis Dam have been constructed across the river and the resulting lakes (Mead and Mojave) have inundated parts of the river valley.

The Colorado River is the only large perennially flowing water body within the planning unit. The numerous washes, etc. within the unit contain water only after rains. EPHEMERAL Rain and snow falling on the eastern Spring Mountains and the eastern portions of the planning unit drains via the ground water aquifers, or the numerous washes, into Lake Mead. Rain falling to the west of the Spring Mountains either becomes part of the aquifers that drain eventually into Death Valley or is evaporated.

The only other surface waters within the planning unit are springs and seeps that occur in various parts of the unit. Most of the springs that occurred in and around Las Vegas are now dry due to over use of the

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Robert J. Bulkowski
January 15, 1973

aquifer. Tule Spring and the spring at Corn Creek are exceptions to this.

About 50,000 acre feet per year of water more than the 340,000 acre feet per year of recharge is being removed from the aquifer at the present time (6). Such over use of the aquifer caused the ground water level to drop an average of ten feet per year between 1960 and 1965 (3), and also caused the land subsidence in and around Las Vegas that was noted by the Mindling (6).

In Nye County to the west of the Spring Mountains and the unnamed hills that parallel them, are another group of springs. These springs flow perennially and are part of the aquifer system that drains into Death Valley. Many contain desert pupfishes. Pumping of the aquifer for irrigation water is lowering the level at Devil's Hole and may eventually affect other springs in the area. It appears that two or more aquifers supply the springs. These springs and aquifers are fed by rain water from other areas. The western Spring Mountains probably supply some water to the aquifer in Pahrump Valley, but most of the ground water in the Pahrump and Ash Meadows area appears to be derived from the mountains and flats that are within the Atomic Energy Commission Test Site (2).

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Robert J. Sniegocki
January 15, 1973

References

Calder, N., 1972. The Restless Earth - a report on the New Geology: Viking Press, N.Y., 152p.

Coffman, J.L., and C.A. von Hake, 1972, United States Earthquakes, 1970: Nat. Oceanic and Atmospheric Admin., Bull. 1-TS6937, 81p.

Cornwall, H.R., 1972, Geology and Mineral Deposits of Southern Nye County, Nevada: Nev. Bur. of Mines, Bull. 77, 49p.

Corps of Engineers, 1967, Flood Plain Information - Lower Las Vegas Wash, Clark County, Nevada: 23p.

Fuhriman and Barton, 1971, Ground Water Pollution in Arizona, California, Nevada and Utah: E.P.A., Water Pollution Control Research Studies, 16060 ERV, 249p.

Joint Panel on Problems Concerning Seismology and Rock Mechanics, 1972, Earthquakes related to reservoir filling: Nat. Tech. Info. Serv., PB-208327, 24p.

Leopold, Wolman, and Miller, 1964, Fluvial Processes in Geomorphology: W.H. Freeman and Co., 522p.

Longwell, et al, 1965, Geology and Mineral Deposits of Clark County, Nevada: Nev. Bur. of Mines, Bull. 62, 218p.

McHarg, I.L., 1969, Design with Nature: Doubleday and Co., Inc., 197p.

Mindling, A., 1971, A Summary of Data Relating to Land Subsidence in Las Vegas Valley: Desert Research Institute, Reno, Nev., 55p.

Pacific Southwest Inter-Agency Committee for the United States Water Resources Council, 1971, The Pacific Southwest Analytical Summary Report on Water and Land Resources: Water Resources Council publication, 185p.

Spencer, E.W., 1962, Basic Concepts of Historical Geology: T.Y. Crowell Co., N.Y., 499p.

U.S.G.S. and Nev. Bur. of Mines, 1964, Mineral and Water Resources of Nev.: Nev. Bur. of Mines, Bull. 65, 314p.

Water Resources Council, 1969, Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies: Water Resources Council, 45p.

Water Resources Council, 1971, Regulation of Flood Hazard Areas to Reduce Flood Losses, Vol. 1, parts I-IV: Water Resources Council, 578p.

Wormington and Ellis (eds.), 1967, Pleistocene Studies in Southern Nevada: Nev. State Museum, Anthro. Papers #13, 411p.

Robert J. Sulenski
May 30, 1973

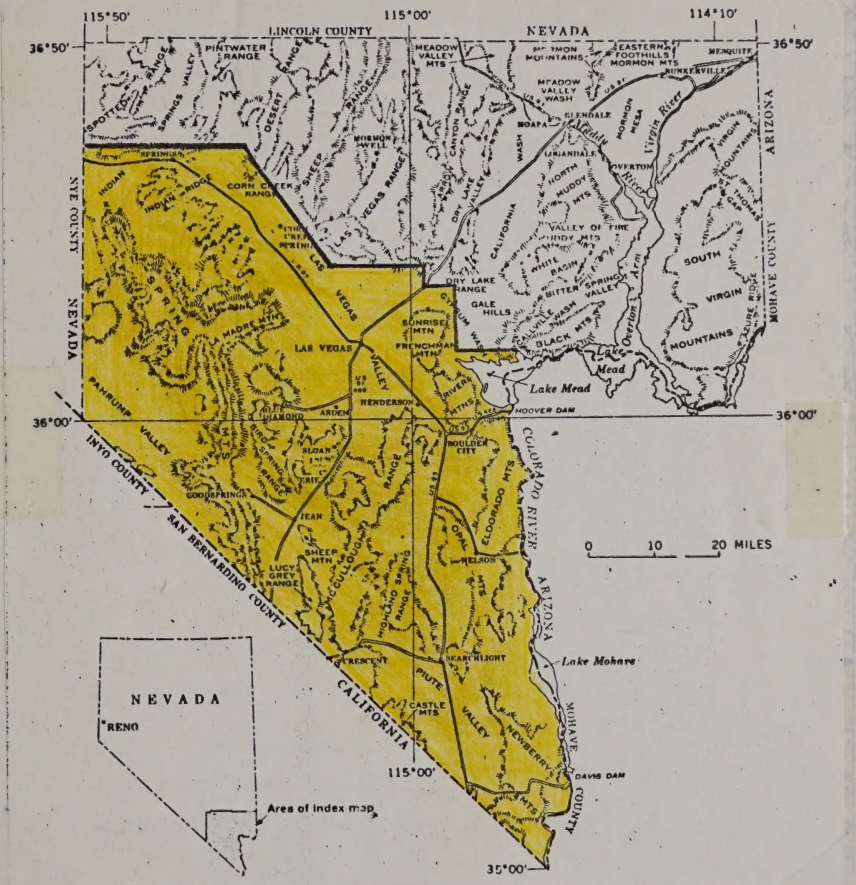

Figure #1: Physiographic features of the Clark County portion of the Stateline Planning Unit (0504). The Planning Unit is in yellow. (From Longwell et al, 1965, Geology and Mineral Deposits of Clark County, Nevada.)

Robert J. Sulenski
January 15, 1973

Figure #1: Physiographic features of the Clark County portion of the Sheckline Planning Unit (0504). The Planning Unit is in yellow. (From Longwell et al, 1965, Geology and Mineral Deposits of Clark County, Nevada.)

Figure #2: Physiographic features of the Nye County portion of the Stateline Planning Unit (0504). The Planning Unit is in yellow. (From Cornwell, 1972 Geology and Mineral Deposits of Southern Nye County, Nevada).

Robert J. Sulenski
January 15, 1973

UNIT RESOURCE ANALYSIS

STATELINE PLANNING UNIT

Water Resources

A. Overlays

Overlay #1 shows water yield and surface water resources.

Overlay #2 shows ground water resources.

B. Tabulations

See various tables and charts within the report.

C. Narrative

1. Hydrographic Areas
2. Climate
3. Topography
4. Surface Water
   a. Streams
   b. Springs
   c. Other sources
5. Ground Water
6. Water Use
7. Water Quality
8. Water for the Future

Meridith 8/73

UNIT RESOURCE ANALYSIS

STATELINE PLANNING UNIT

.35 Water Resources

A. Overlays

Overlay #1 shows water yield and surface water resources.

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C. Narrative

1. Hydrographic Areas

2. Climate

3. Topography

4. Surface Water

a. Streams

b. Springs

c. Other sources

5. Ground Water

6. Water Use

7. Water Quality

8. Water for the Future

C. Narrative

The Stateline Planning Unit is plagued by a lack of standing surface water, as is the rest of Nevada. It must rely on springs and wells to satisfy its water needs. The decreasing quality and quantity of water from these sources present a serious problem.

1. Hydrographic Areas

The Stateline Unit includes part of two hydrographic regions - the Central Region and the Colorado River Basin. It can then be divided into ten hydrographic areas: Colorado River Valley (563 sq. mi.), Piute Valley (338 sq. mi.), Eldorado Valley (530 sq. miles), Hidden Valley South (34 sq. miles), Jean Lake (96 sq. miles), Ivanpah Valley (326 sq. miles), Mesquite Valley (236 sq. miles), Pahrump Valley (789 sq. miles), Las Vegas Valley (1,564 sq. miles) and the Amargosa Desert (896 sq. miles). All of the Amargosa Desert is not, however, within the border of this Planning Unit.

2. Climate

Of course, one of the primary reasons for the low availability of water in the Stateline Planning Unit is the arid climate characteristic of the State of Nevada. Precipitation varies with altitude and ranges from as little as 3.76 inches per year at Lathrop Wells in the Amargosa Desert (Walker and Eakin, 1963) to over 20 inches at Charleston Peak (11,918 ft.). The average for the whole region is only 6.5 inches or 2,027,000 acre feet per year (see Table 1).

c. Narrative

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f. Hydrographic Areas

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Most of this precipitation falls during the winter months. The small amount that falls during June, July and August is rapidly evaporated by a combination of high temperatures, large amounts of sunshine, strong winds and a low relative humidity (Maxey and Jameson, 1948).

3. Topography

Topography is another factor affecting the amount of available water. The Stateline Planning Unit can be divided into three types of physiographic provinces: mountains, alluvial aprons and the basin low lands.

a. The parallel, elongated mountain ranges have steep barren slopes composed of consolidated, impervious rock. They are the principle sites of erosion and are scarred with deep ravines and canyons carved by mountain streams (Maxey and Jameson, 1948). The major ranges include the Spring, Eldorado and McCullough Mountain Ranges.

b. There is an abrupt change in altitudes and materials as one moves onto the alluvial aprons. They are composed of coarse, angular debris (gravel, sand, silt, clay) deposited in the past by streams as they diverged on the gentle slopes. Water is lost on the aprons due to infiltration, evaporation and transpiration (Lamke and Moore, 1965). Since there is little vegetation here, erosion is now occuring on aprons in Las Vegas and Pahrump Valleys (Maxey and Jameson, 1948).

c. The surfaces of the basin lowlands are smooth and nearly level. Water may stand and accumulate here. The lowlands are common sites for the deposition of fine-grained lacustrine wash and eolian materials (Maxey and Jameson, 1948). An exception to this rule is the Amargosa Desert, a topographically open basin where the playas or flat areas have begun to erode (Walker and Eakin, 1963).

Both the alluvial aprons and the valley floors consist of unconsolidated permeable sediments.

4. Surface Water

a. Streams

The Colorado River lies along the Nevada-Arizona border but no rivers are located entirely within the Stateline Planning Unit and there are no large, perennial streams. Las Vegas Wash, one of the largest surface waterways, carries large amounts of waste water from the Las Vegas Valley area to the Colorado River system. In 1967, it was being gaged at only one station near Henderson. Its average discharge measured 16,000 acre feet (Rush, 1968). Its heaviest discharge is during the winter months (November to January) when rainfall is heaviest (State Engineer, 1971).

b. Springs

Springs (concentrated discharges of ground water at the land surface) are more prevalent. The most important perennial springs are those occuring in the valleys. They originate as underground currents of water in alluvial apron gravels. When these channels of water come into

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contact with impervious rock along fault lines, they are forced to the surface. Las Vegas, Tule, Bennetts and Manse Springs are examples of valley springs that discharge relatively steady flows of water throughout the year (Maxey and Jameson, 1948).

Mountain springs, unlike those in the valleys, discharge fluctuating amounts of water during the year. The Spring Mountain area contains a few large and many small springs which flow in the spring, but simply dry up in the late summer or early fall (Maxey and Jameson, 1948).

Table 2 is a list of the larger springs in the Stateline Planning Unit.

c. Other Sources

A reservoir is defined as a pond, lake or basin, natural or artificial, that is used for the storage, regulation and control of water. There are no large reservoirs entirely within the planning unit, but Lake Mohave and Lake Mead along the Nevada-Arizona border are very important to the people in the Stateline area. These multi-purpose sources of surface water have 1,820,000 and 29,700,000 acre-foot capacities respectively (State Engineer, 1971).

Still another, but minor, source of surface water is snow cover. Snow surveys have been conducted in the Spring Mountains. The average water content of snow in several areas over 8,000 feet in elevation is shown in Table 3.

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Table 4 gives an indication of the limited amounts of surface water available to the different basins. After some precipitation has evaporated and some more has seeped into the ground, only about 35,000 acre feet are left as runoff to replenish surface water supplies. Therefore, the Stateline Planning Unit must rely mainly on its ground water resources.

5. Ground Water

Most of the ground water in the Stateline Unit is derived from precipitation in higher elevations of Spring and Sheep Mountains. About 20% of the precipitation at elevations of 6-8,000 feet and 25% of that which falls above 8,000 feet percolates into the earth to recharge ground water reservoirs (Maxey and Robinson, 1947). The amount of recharge totals about 52,700 acre feet each year in the Stateline region (see Table 5).

The supply of ground water can also be recharged naturally by infiltration of water from lower levels and artificially by sewage effluent, leaky wells and water imported from other sources like Lake Mead (Malmerg, 1961). Exact figures for these amounts of recharge are not known.

The four hydrologic zones of rock and soil that contain this economically important ground water are the deep, middle, shallow and near surface aquifers. The deep, middle and shallow zones make up the artesian system (see Figure 1).

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The deep zone is composed of sand, silt and clay and has a low permeability. Only a few wells can extract water from this layer buried 700 feet below the surface.

The middle and shallow zone aquifers, composed of permeable gravel, sand, silt and clay provide more than 3/4 of the ground water received by wells and springs. They are encountered between 200 and 700 feet deep (Maxey and Robinson, 1947).

Lenses of caliche, sand, silt and clay make up the near surface zone 1-50 feet underground. This level may be saturated with water but much of it is unavailable because of poor quality, inaccessibility (low permeability of the soil makes extraction difficult) or loss through evapotranspiration.

The near surface layer is recharged by water leaking up along fault zones, leaky deep wells, waste irrigation and sewage water. The water level here is subject to seasonal fluctuations of 1-3 feet (highest in April-May, lowest in September-October). These fluctuations could reflect seasonal changes in the artesian system or changes in evapotranspiration rates during the year (Maxey and Jameson, 1948).

Table 5 reveals other facts about the ground water resources in the Stateline Planning Unit.

The water budget figures represent ground water inflow and outflow for the various valleys. The total ground water budget for the region is less than 101,700 acre-feet per year.

The quantity of ground water in storage that is shown in the table is approximately 1% of the volume of saturated valley fill.

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The actual storage capacity in the upper 100 feet of alluvium is then 100X the total shown or 11,690,000 acre-feet.

The amount of this which can be withdrawn each year without badly lowering the water table is called the perennial yield. The perennial yield for the Stateline Unit is 75,300 acre-feet per year.

But the large figures for water budget, storage and perennial yield are deceiving. A large amount of the ground water in the Planning Unit is either inaccessible or unusable.

Phreatophytes, for instance, are plants-mesquite, willow, cottonwood, arrowweed, saltbush - which absorb ground water through their roots and release it as transpiration into the atmosphere. They are an important source of ground water loss in some areas because they can tap water up to 50 feet below the surface (State Engineer, 1971). Phreatophytes and direct evaporation from the soil account for more than 60,000 acre-feet of water loss in the Amargosa Desert and Colorado, Mesquite, Pahrump and Las Vegas Valleys (see Table 5).

Then, too, a lot of ground water in the Stateline Unit is unusable because of poor quality (see section on "Water Quality").

6. Water Use

a. General

Water use in the Stateline Planning Unit can be divided into the following categories: 1) irrigation, 2) public supply, 3) industrial use, 4) electric power, 5) domestic use and 6) other nonconsumptive uses.

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Irrigation water is composed of water diverted or pumped for crops, pasture, landscaping, athletic fields and parks. The amount of water used for irrigation in Nevada has remained relatively stable over the years. However, use for crops and pasture is being replaced by use for lawns, parks and golf courses as the urban population grows (State Engineer, 1971).

Public supply water is that water delivered to a public water system by both large municipal systems and privately-owned companies. Unlike irrigation, public use has been increasing rapidly and will continue to as the population grows. (Figure 2 and Table 6 demonstrate the rate of population growth in the Clark County and the Colorado River Basin.)

Industrial use water is water used for mining, manufacturing, hotels, restaurants, casinos, institutions. Industrial use was one of the first major uses of water in Nevada; from 1849-1860 most water was used in mining (State Engineer, January, 1971). In certain areas, mining and industry still play an important role in water use. Table 7 shows increasing demand of indoor and municipal uses combined.

Electric power water is water used by public utilities for hydroelectric power and for cooling. In general, little of the water withdrawn for power generation is actually consumed (State Engineer, January, 1971).

Domestic use is water withdrawn for livestock and homes not supplied by public water systems.

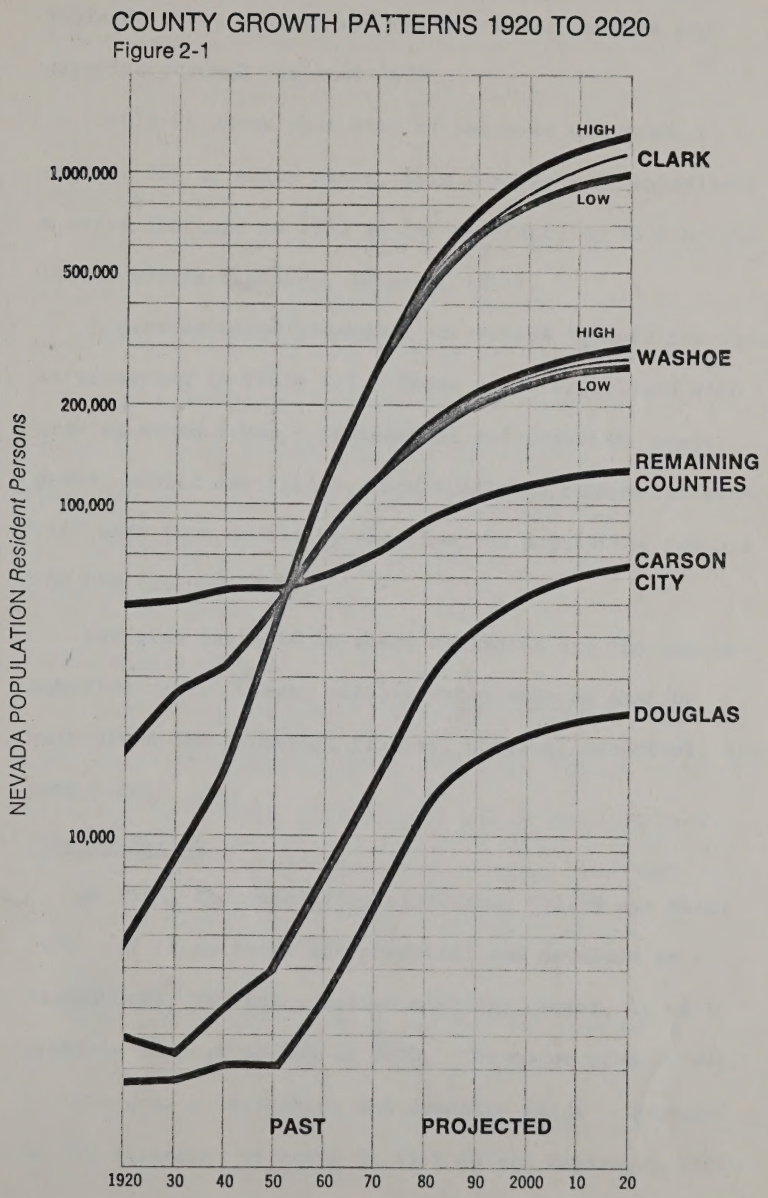
Finally, water is needed for recreation and wildlife/fisheries resources. As interest in ecology and returning to nature grows, the demand for these non-consumptive uses of water will grow.

The amounts of water needed and the higher priority uses for water vary from place to place in the Planning Unit. The following discussion takes a closer look at the requirements of each area.

b. Las Vegas Metropolitan Subarea

This subarea (2,000 sq. miles) consists of Las Vegas, North Las Vegas, Henderson and Boulder City. The population in 1973 is about 311,000 people. There are five major agencies that distribute water in this subarea: Las Vegas Valley Water District, cities of North Las Vegas and Henderson, Nellis Air Force Base and Basic Management Industries, Inc. Boulder City gets water from Lake Mead through the Bureau of Reclamation (Necon, 1973).

Figure 2


COUNTY GROWTH PATTERNS 1920 TO 2020
Figure 2-1
NEVADA POPULATION Resident Persons
1,000,000
500,000
200,000
100,000
10,000
HIGH
CLARK
LOW
HIGH
WASHOE
LOW
REMAINING COUNTIES
CARSON CITY
DOUGLAS
PAST
PROJECTED
1920 30 40 50 60 70 80 90 2000 10 20

The Las Vegas Metropolitan subarea is the fastest growing in the state. The population is expected to reach 1.1-1.2 million in the year 2020 (see Figure 3). This growth will be reflected in the skyrocketing demands for water. Table 8a shows minimum and maximum water demands and supplies through the year 2020.

Table 8b shows that even if measures are taken to reclaim 30% of waste water, this subarea will experience a water shortage in 1993 at the earliest, in 2008 at the latest (State Engineer, January, 1971).

A more detailed breakdown of various demands for water is presented in Table VII. Those needs associated with growing urban areas - residential and transient needs, parks, public facilities, industrial and commercial uses - will more than double by the time the population reaches 700,000 (around 1990).

Not even included in these estimates are the nonconsumptive uses. Clean, potable water sources must be maintained for swimming, fishing, boating, waterfowl, big game, etc.

c. Pahrump Valley

In 1971, the population of Pahrump Valley was about 1200. If it fulfills its potential and develops as a second home, tourist - casino activity center, it will probably support 10,000 in 2020. The major uses of water in this area - irrigation and domestic needs - consumed 48,000 acre-feet of water in 1968 (State Engineer, 1971).

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Discharge from wells and springs in 1971 was 49,000 acre-feet while the perennial yield (see Table 5) was only 12,000 acre-feet. But there is a large stored quantity of good ground water (> 2 million acre-feet) that can be tapped to provide enough for Pahrump's future population with some to spare for other parts of the state (State Engineer, 1971).

d. Mesquite Valley

Table 10 shows the present annual average consumption of the valley; the population of 30 people and 100-200 head of livestock consume 5 acre-feet while irrigation uses about 1400 acre-feet per year (State Engineer, 1971). There are presently 60 wells in the areas and the 2200 acre-feet of perennial yield should provide for the needs of the people in the community and any future agricultural development (Glancy, 1968).

e. Goodsprings, Jean

Goodsprings and Jean, two towns in the southwestern section of the Planning Unit, presently support about 380 people. In 1966-67, they consumed only about 30 acre-feet of domestic and public supply well-water (see Table 10). These communities, thus, have a plentiful supply of ground water.

It is difficult, however, to predict whether or not they will have enough to satisfy future needs. "The Water Quality Management Plan (1973)" listed the following population growth figures for Goodsprings.

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1970 - 310	1990 - 400
1975 - 320	1995 - 450
1980 - 350	2000 - 500
1985 - 370	

Jean's population may similarly increase if the tourist industry is developed there. In this case, the perennial yield of 1,000 acre-feet in the Ivanpah Valley - Jean Lake area (see Table 5) may not be enough to meet demands.

But if tourist industry is not developed, the population in this area may not increase at all and the perennial yield will more than suffice.

f. Southeastern Clark County Subarea

This subarea includes Searchlight, Nelson, Fort Mohave and recreation sites along the Colorado River. The municipal use of water is expected to increase, especially if a major new urban development is created at Fort Mohave. The following population growth will probably occur if the new community is developed (Necon, 1973):

1970 - 360	1990 - 17,000
1975 - 410	1995 - 19,000
1980 - 500	2000 - 23,000
1985 - 5,000	

Again it is difficult to determine exact water needs and this area's ability to meet them in the future. According to State Engineer (1971) some of the possible demands in later years are:

Southern California Edison	0-30,000 af/yr
Beaumont & Associates	11,000
Colorado River Prop.	1,200
Rio Alto Visa	380
Konig	400

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Beaumont & Associates	11,000
Colorado River Prop.	1,200
Rio Alto Vista	330
Konig	400

Ft. Mojave Indians and national recreation area	6,000
Miscellaneous small users	20

This means demands in the southeastern subarea could reach 19,000-49,000 acre-feet per year (State Engineer, January, 1971). When and if needs will ever get this high is not certain. Most likely shortage of water in the area will discourage such massive development. For the Eldorado-Colorado-Piute Valley area, perennial yield only amounts of 1100 acre-feet and another 37,000 acre-feet is present in storage (Table 5).

Nonconsumptive use can and will continue to grow here. Boating, fishing, fish hatcheries, wildlife habitat and power generation at Hoover Dam do not require permanent withdrawal of water.

g. Amargosa Desert

About 1,200 of the 1,500 people living in this area live in Beatty, outside the boundaries of this Planning Unit. It is unlikely that any great development will occur in this subarea; only a minor amount of water is consumed for industry and agriculture.

This is an example of an area in which nonconsumptive use have come into conflict with withdrawal use in the Ash Meadows area. Water levels have been adversely affected by heavy pumping for irrigation and domestic use. Courts have issued injunctions limiting the amount of pumping allowed in order to protect endangered species of desert

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fish in the area. This means that there will be a limit to the amount of development that can occur and that demand will probably balance supply in the future.

7. Water Quality

a. General

One of southern Nevada's most crucial hydrology problems is the poor quality of much of the surface and ground water. Ideally over 11 million acre-feet of ground water in storage could be tapped for industrial, public supply and irrigational uses. But excessive concentrations of sulfates, nitrates, dissolved solids, etc. are inhibiting use of this water in certain areas.

Several factors contribute to the high quantities of chemicals and solids in Stateline Unit water. First of all, the high evaporation rates leave a high concentration of salts at or near the surface of the soil after a rainfall. Secondly, the slow movement of water into and through the soil dissolves metallic and non-mettalic substances — sulfides, borate, gypsum, halite, etc.—prevalent in soil and rock. Finally, dust (containing salts) is blown from playas onto standing surface water and onto soil where it is washed into ground water supplies during storms (Davis and DeWiest, 1966).

Table 11 shows the Public Health Service's Standards for public supply and domestic water (1962). Each chemical has a different effect on drinking water. Excess dissolved

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Table II shows the Public Health Service's Standards for public supply and domestic water (1962). Each chemical has a different effect on drinking water. Excess dissolved

solids and chloride give water a brackist taste. Too much sulfate can have a laxative effect. Excess fluoride is especially hazardous to children (stains teeth) and nitrates can cause methemoglobinemia (blue-baby disease) if consumed by infants or pregnant women (Rush, 1968).

The chemical substances listed in Table II should not be present in a water supply in excess of the listed concentrations where, in the judgment of the reporting agency and the certifying authority, other more suitable supplies are or can be available (attached).

The standards are different for irrigational water. For instance while only 1,000 parts per million (ppm) is acceptable for public supply, up to 2,000 ppm is acceptable for irrigation (Maxey and Jameson, 1948). Also, boron, sulfate, and chloride concentrations and salinity and sodium hazards become especially crucial when talking about crops.

Still other guidelines can be used when discussing industrial use.

Here chemicals like sulfate and chloride that cause corrosion or that cause formation of scale in boilers and pipes are a problem. "Hardness" (determined by amounts of magnesium and calcium) affects almost all the water in the Stateline Planning Unit. The U.S. Geological Survey (Glancy and VanDenburgh, 1969) uses the following ratings:

Hardness Range (mg/l)	Rating
0-60	Soft
61-120	Moderately hard (softening needed for laundries)
121-180	Hard (softening needed by laundries and some industries)
>180	Very Hard (softening needed for most purposes)

In this unit most ground water is rated "very hard".

For nonconsumptive uses like recreation and wildlife habitat, aesthetics (appearance, smell) become important. Amounts of nutrients (phosphorus, nitrogen), oxygen and degree of alkalinity must be properly balanced.

b. Las Vegas Valley

Las Vegas Valley is having problems in obtaining supplies of potable irrigation and industrial water. As the population continues to grow and surpasses 700,000, the overdraft will further increase total dissolved solids (TDS) and decrease water quality.

1) Surface Water

Tables 12-15 show chemical analyses of surface water sources in the Stateline Unit. Excess TDS is a common problem in Colorado River (675-711 mg/l), Lake Mead (688 mg/l), Grapevine (> 2000 mg/l) and Cottonwood Springs (563 mg/l). Sulfate also exceeds the recommended limit in Lake Mead. Treatment is usually necessary to remove these problems before this surface water can be used for irrigation and drinking.

Hardness Range (mg/l)	Rating
0-60	Soft
61-120	Moderately hard (softening needed for laundries)
121-180	Hard (softening needed by laundries and some industries)
>180	Very Hard (softening needed for most purposes)

In this unit most ground water is rated "very hard".

For nonconsumptive uses like recreation and wildlife habitat, aesthetics (appearance, smell) become important. Amounts of nutrients (phosphorus, nitrogen), oxygen and degree of alkalinity must be properly balanced.

b. Las Vegas Valley

Las Vegas Valley is having problems in obtaining supplies of potable irrigation and industrial water. As the population continues to grow and surpasses 700,000, the overdraft will further increase total dissolved solids (TDS) and decrease water quality.

1) Surface Water

Tables 12-15 show chemical analyses of surface water sources in the Stateline Unit. Excess TDS is a common problem in Colorado River (675-711 mg/l), Lake Mead (688 mg/l), Grapevine (> 2000 mg/l) and Cottonwood Springs (363 mg/l). Sulfate also exceeds the recommended limit in Lake Mead. Treatment is usually necessary to remove these problems before this surface water can be used for irrigation and drinking.

A particularly bad case in Las Vegas Valley is Las Vegas Wash which carries municipal sewage and waste water from Southern Nevada Power Company and Henderson Industries. As can be seen in Table 15, it carries excessive amounts of almost every substance which inhibits its use for public supply, irrigation and recreation. Without extensive, expensive treatment, it can only be used for industrial cooling.

2) Near Surface Water

In Las Vegas Valley Subarea (especially in Paradise Valley and near Las Vegas Wash), most of the near surface water contains large quantities of Ca, Mg and $NaSO_4$ (650-3000 ppm) and is unsuitable for irrigation or domestic use. It can, however, be used for cooling (Maxey and Jameson, 1948).

3) Artesian Water

Tables 16 and 17 show chemical analyses of various wells throughout the Las Vegas Valley Subarea. All the waters are very hard. But the quantities of dissolved solids, sulfates and other compounds vary.

The well water near Whitney and Pittman (Tps 21 and 22S., R.62E.) and in the Henderson area contains high amounts of dissolved solids, most in the form of calcium sulfate. This water reflects the highly mineralized character of the valleyfill (eroded from mountains containing gypsum, limestone and dolomite)

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through which it passes. The combination of high sulfate (> 1600 ppm) and TDS (> 2000 ppm) concentrations limits this water's use for public supply and irrigation (Maxey and Jameson, 1948).

Well water near Pittman and Whitney is also contaminated by excess sodium and chloride (Maxey and Jameson, 1948). The water contains from 47-81% sodium (> 60% is considered unsafe for agriculture) and 300-500 ppm chloride (over 300 ppm can be harmful to plants).

The ground water in the rest of the valley (Las Vegas and Tule Springs, Paradise Valley, North Las Vegas, Spring Mountains) has a low sodium hazard, but for most purposes must be treated to remove hardness and TDS.

c. Mesquite-Ivanpah-Jean Lake

Table 18 is a chemical analysis of ground water in Mesquite, Ivanpah and Jean Lake Valley. The salinity hazard is an expression of the dissolved solids content while the alkalinity hazard refers to the ratio of sodium to calcium and magnesium. In most areas the alkalinity hazard is low. The salinity hazard tends to be high, but with proper drainage and choice of crops, this water is safe for irrigation (Glancy, 1968).

8/73

The quality of ground water in most of Jean Lake and Hidden Valley is not known because few analyses have been conducted there. It would be worthwhile to do more research in these areas; new sources of potable ground water may be made available.

d. Pahrump

Tables 14 and 19 are chemical analyses of ground and surface water in Pahrump. The water quality is relatively good in Pahrump and is useful for most purposes once it's treated for hardness. About 100 wells are presently discharging 48,000 acre-feet of ground water for domestic use (State Engineer, 1971).

e. Goodsprings, Jean

The well water in Jean shows excessive amounts of TDS ($>$1500 mg/l) and chloride ($>$ 700 mg/l), which limits its use for irrigation (see Table 20). Goodsprings also has a high TDS concentration ($>$ 500 mg/l) in its ground water. In both cases the supply is pumped at individual buildings from shallow wells. Organic pollution contributes to the poor quality of water in these areas (Necon, 1973).

f. Southeastern Clark County

Table 21 is a chemical analysis of ground water in Nelson. Again TDS and hardness (in the form of $CaCO_3$) are the major problems. In nearby Searchlight good well water is available from the rock formation one mile west of the community (Necon, 1973).

8/73

More research is needed to estimate quantity and quality of ground water in this region.

g. Amargosa Desert

This area gets much of its water from springs in the Ash Meadows region which discharges about 17,000 acre-feet per year. The ground water here is extracted from wells which average 300 feet deep and yield about 500 gpm each (State Engineer, 1971).

Table 22 rates the water sources according to irrigation class. Most of the water within the Stateline Unit is either C2 or C3 salinity hazard. This means that salinity is high and special management (salt-tolerant plants, good drainage) is necessary. Practically all the water has a S1 rating, though, meaning that there is little danger of harmful levels of sodium being developed (Walker and Eakin, 1963).

Boron is still another problem that requires attention if this water is to be used for irrigation purposes. A small amount of boron is essential to crops, but any more than .3 ppm can be deadly. Table 22 shows the boron range to be between .1 and 1.4 ppm. Either the boron has to be removed or only tolerant crops can be planted.

The water in the Amargosa Desert can be used for municipal and industrial purposes if treated to remove the high level of flouride. The concentrations of the analyses shown range from .6-3.2 ppm. As stated before untreated water high in fluoride ($\geq$.8 ppm) can be harmful to children's teeth.

8/73

More research is needed to estimate quantity and quality of ground water in this region.

8. Amargosa Desert

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Boron is still another problem that requires attention if this water is to be used for irrigation purposes. A small amount of boron is essential to crops, but any more than .3 ppm can be deadly. Table 22 shows the boron range to be between .1 and 1.6 ppm. Either the boron has to be removed or only tolerant crops can be planted.

The water in the Amargosa Desert can be used for municipal and industrial purposes if treated to remove the high level of fluoride. The concentrations of the analyses shown range from .6-3.2 ppm. As stated before untreated water high in fluoride (2.8 ppm) can be harmful to children's teeth.

8. Water For The Future

Lack of quantity and quality will hinder the Stateline Planning Unit's ability to meet increasing demands for potable water in the future. The problem will be most critical in the populous Las Vegas Valley. There have been numerous suggestions (some sensible, some farfetched and impractical) on how to correct the situation. The following is a very brief summary of some of the recommendations that have been made. For more details, refer to "Water for Nevada" (State Engineer, January, 1971), "Report on Southern Nevada Water Supply Project" (Udall, Dominy and West, 1963) and "Water Quality Management Plan" (Necon, 1973).

a. Plans to Increase Water Quantity

There are three approaches to the problem of water quantity. The first one is to enlist the public's help in conserving water. This can be done by limiting low value uses (set up certain hours for car washing, lawn sprinkling), charging higher prices for water (which would in turn lead to self-imposed limits on low value uses) and through education of the public (explaining the problem and what the individual consumer can do to help). Table 23 estimates the effect of such measures.

The second approach is the use of technology to create new sources of water and prevent water loss. Research is presently being conducted in cloud seeding, ways to cut down evaporation from reservoirs, and in how

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to best eliminate non-beneficial phreatophytes (State Engineer, 1971). There's no telling when such scientific break throughs will be made.

The third approach is to import water from other areas. The Southern Nevada Water Project was created by the U.S. Congress in 1965. It's purpose is to deliver water for municipal and industrial use from Lake Mead. Its complex system of pumping plants, aqueducts and transmission lines was begun in 1971 (Phase I) and should be finished by 1980 (Phase II). In 1971, 132,000 af was imported under Phase I (State Engineer, 1971).

In this same vein, there's talk of intrastate transfer of water from Pahrump, Amargosa, Railroad, Pahranagat and Virgin Valleys. Such aqueduct systems would deliver a maximum rate of 135% of the projected daily use in 2020. Such systems would also be very expensive (State Engineer, 1971).

Still another proposal is the North American Water and Power Alliance (NAWAPA), which recommends interstate diversion of water from Alaska and Canada into the southwestern U.S. This plan is probably politically unfeasible. Desalination could also be used to provide good quality, treated seawater from the Pacific Ocean. But this suggestion is both economically and technologically unsound at the present moment (State Engineer, 1971).

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In the campaign to increase quantities of available water, economization of water use is the most practical approach for the present.

b. Plans to Improve Water Quality

There are already a few operations underway to improve water quality through the treatment and recycling of waste water. Waste water treatment systems are supposed to be constructed in North Las Vegas and expanded at existing sites in Las Vegas, Henderson and Clark County Sanitation District. Also efficient ways of constructing sanitary landfills are being sought in order to reduce pollution of ground water. Effective lining of evaporation ponds will also minimize pollution of ground water.

The Environmental Assessment Pollution Abatement Project (VTN Nevada/Jones and Stokes, 1972) gave several long-range alternatives for the improvement of water quality in Las Vegas Valley:

1) Complete treatment of waste water before its discharge into Lake Mead or Las Vegas Wash. This is the most ecologically favorable plan but also the most expensive.

2) Portion of waste water treated and retained for in-valley uses while the rest is exported to Dry Lake for evaporation. This may be the most feasible plan.

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3) Ground water recharge by injecting treated sewage into aquifers beneath Las Vegas Valley. This alternative is still technologically unproven and further testing is needed.

4) Return water to the Colorado River after extensive treatment and refrigeration.

5) Export all municipal waste water to Dry Lake for evaporation. This would improve the quality of water in Las Vegas Bay but significantly decrease the supply of water to Las Vegas Wash (for wildlife habitat), Lake Mead (power generation, recreation), and Boulder Canyon (multiple use).

c. Conclusions

The problem of providing more water for the Stateline Planning Unit is a complex and perhaps insolvable one. Water economization by government, industry and the public can be put into effect immediately through higher rates and an intensive "save water" publicity campaign. But this will only level off water demands temporarily; none of the suggested methods of water conservation can compete with increasing population pressures for long.

It can only be hoped that one of the longer ranged alternatives - either a successful pollution abatement or water importation program-will be able to supply enough water at a reasonable cost. Otherwise water shortages in the future will curtail development in parts of the Planning Unit or cause a reduction in water use for certain

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Table 4.--Average monthly and annual precipitation, in inches, at selected stations

/From published records of the U.S. Weather Bureau/

Station 1/	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Boulder City	0.63	0.52	0.51	0.41	0.17	0.06	0.49	0.57	0.49	0.38	0.44	0.58	5.22
Las Vegas Airport	.46	.33	.40	.28	.08	.04	.47	.44	.37	.26	.38	.38	3.89
Pahrump	.31	.49	.13	.34	.05	T.	.17	.26	.32	.22	.77	.57	3.64
Red Rock Summit	1.20	.73	1.39	.76	.41	.25	1.08	1.29	.48	1.14	.64	1.75	10.62
Roberts Ranch	1.30	1.26	1.84	.97	.49	.25	1.12	1.21	.60	1.49	.96	2.06	13.95
Searchlight	.86	.82	.68	.50	.20	.14	.96	1.17	.61	.49	.43	.80	7.71

1. See table 3 and figure 2 for station locations and period of record.

Table 2

Major Springs in Stateline Resource Area

Spring	Discharge (gal./min.)
Hotcreek	4,000e
Crystal Pool	2,800
Pahrump (Bennetts)	2,500
Fairbanks	1,700
Las Vegas Springs	1,400
Point of Rocks	1,100
Big Spring	1,000
Longstreet	1,000
Diana's Punch Bowl	900e
Rogers	740
Jack Rabbit	590
Manse	500e
Charnock	450e
Potts Ranch	450e
Darroughs Hot	450e
Kyle[1]	405
Willow	340
Tule	300
Cottonwood	225

[1] Maxey and Jameson, 1948

e Estimate

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Potts Ranch	450e
Barroughs Hot	450e
Kyle	405
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Cottonwood	225

[1] Maxey and Jameson, 1948

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Table 3

WATER CONTENT IN SNOW PACK - SPRING MOUNTAINS 1/
Southern Nevada Water Supply Project, Nevada

Course	Elevation	Water Content as of April 1, 1962 (inches)	Past Record Average Water Content (inches)
Clark Canyon	9,000	13.7	8.5 2/
Kyle Canyon	8,200	20.1	9.5 2/
Lee Canyon No. 1	8,300	16.9	8.0
Lee Canyon No. 2	9,000	18.8	9.6 2/
Rainbow Canyon No. 2	8,100	26.1	16.0 2/
Trough Springs	8,500	10.9	6.2 2/

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1/ Source: Water Supply Outlook and Federal-State-Private Cooperative Snow Surveys for Nevada. U. S. Department of Agriculture, Soil Conservation Service, and Nevada Department of Conservation on Natural Resources Division of Water Resources.

2/ 1943 - 57 adjusted average which is used as the basis in forecasting water yield.

TABLE 4 SURFACE WATER RESOURCES STATELINE PLANNING UNIT

Hydrographic Area	Runoff From Mts. (Ac. Ft./Yr.)	Annual Precipitation (In.)	Total Precipitation (Ac. Ft./Yr.)	Evaporation (Ac. Ft./Yr.)
Colorado River Valley	Minor	4.8	150,000	Large
Piute Valley	100	6	110,000	-
Eldorado Valley	100	7.2	190,000	Minor
Hidden Valley (South)	50	6	11,000	Minor
Jean Lake	250	6	32,000	Minor
Ivanpah Valley				
Northern Part	1,200	6	81,000	Minor
Southern Part	Minor	7.2	33,000	Minor
Mesquite Valley	1,700	7.2	90,000	Minor
Pahrump Valley	13,000	8.4	420,000	Some
Las Vegas Valley	19,000	8.4	660,000	Minor
Amargosa Desert*	50	4.8	240,000	Some
	35,450	6.5	2,027,000	

* Not all of this hydrographic area is within the Planning Unit

State Engineer, October, 1971.

TABLE 4 — SURFACE WATER RESOURCES — STARTLINE PLANNING UNIT

Hydrographic Area	Runoff From Mts. (Ac. Ft./Yr.)	Annual Precipitation (In.)	Total Precipitation (Ac. Ft./Yr.)	Evaporation (Ac. Ft./Yr.)
Colorado River Valley	Minor	4.8	150,000	Large
Pirate Valley	100	6	110,000	-
Bidorado Valley	100	7.2	190,000	Minor
Hidden Valley (South)	50	6	11,000	Minor
Jean Lake	250	6	32,000	Minor
Ivanpah Valley	1,200	6	81,000	Minor
Northern part	Minor	7.2	33,000	Minor
Southern part				
Mesquite Valley	1,700	7.2	90,000	Minor
Paiute Valley	13,000	8.4	420,000	Some
Las Vegas Valley	19,000	8.4	660,000	Minor
Amargosa Desert*	50	6.8	240,000	Some
	35,450	6.5	2,027,000	

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State Engineer, October, 1971.

TABLE 15 GROUND WATER RESOURCES STATELINE PLANNING UNIT

Hydrographic Area	Water Budget (Ac. Ft./Yr.)	Perennial Yield (Ac. Ft./Yr.)	Ground Water in Storage (Ac. Ft/Yr.) per foot	Recharge From Precipitation (Ac. Ft./Yr.)	Evapo-Transpiration (Ac. Ft./Yr.)
Colorado River Valley	200	Minor	11,000	200	Large
Piute Valley	1,100	600	12,000	1,100	0
Eldorado Valley	1,100	500	14,000	1,100	0
Hidden Valley (South)	Minor	Minor	800	Minor	0
Jean Lake	100	50	3,200	100	0
Ivanpah Valley					
Northern Part	1,500	700	7,400	700	0
Southern Part	500	250	1,000	500	0
Mesquite Valley	2,200	2,200	7,000	1,400	2,000
Pahrump Valley	22,000	12,000	23,000	22,000	10,000
Las Vegas Valley	30,000	25,000	34,000	25,000	24,000
Amargosa Desert*	43,000	34,000	3,500	600	24,000
	101,700	75,300	116,900	52,700	60,200

* Not all of this hydrographic area is within Planning Unit boundaries

State Engineer, 1971 (Oct.)

TABLE 2.5 GROUND WATER RESOURCES STATELINE PLANNING UNIT

Hydrographic Area	Water Budget (Ac. Ft./Yr.)	Perennial Yield (Ac. Ft./Yr.)	Ground Water in Storage (Ac. Ft/Yr.)	Recharge From Precipitation (Ac. Ft./Yr.)	Evapo-Transpiration (Ac. Ft./Yr.)
Colorado River Valley	200	Minor	11,000	2000	Large
Piute Valley	1,100	600	12,000	1,000	0
Eldorado Valley	1,100	500	14,000	1,100	0
Hidden Valley (South)	Minor	Minor	800	Minor	0
Jean Lake	100	50	3,200	100	0
Ivanpah Valley					
Northern Part	1,500	700	7,400	700	0
Southern Part	500	250	1,000	500	0
Mesquite Valley	2,200	2,200	7,000	1,400	2,000
Pahrump Valley	22,000	12,000	23,000	22,000	10,000
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Amargosa Desert*	43,000	34,000	3,500	600	24,000
	101,700	75,300	116,900	52,700	60,200

* Not all of this hydrographic area is within Planning Unit boundaries

State Engineer, 1971 (Oct.)

Table 6

Population Growth

Clark County

1920	4,859
1930	8,532
1940	16,414
1950	48,289
1960	127,016
1970	273,288
1980	483,000
1990	715,000
2000	894,000
2010	1,016,000
2020	1,087,000

Colorado River Basin

1970	272,000
1980	476,000
1990	708,000
2000	886,000
2010	1,007,000
2020	1,075,000

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2020	1,075,000

Table 7

Industrial and Municipal Use*

Clark County

Year	Acre-Ft./Yr.	Per Capita Per Day
1970	133,000	435
1980	249,000	445
1990	392,000	455
2000	521,000	465
2010	625,000	475
2020	706,000	485

Colorado River Basin

Year	Acre-Ft./Yr.	Per Capita Per Day
1970	134,000	440
1980	242,000	455
1990	365,000	460
2000	467,000	470
2010	542,000	480
2020	591,000	490

* Includes domestic use

State Engineer, 1973

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Clark County

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1970	133,000	435
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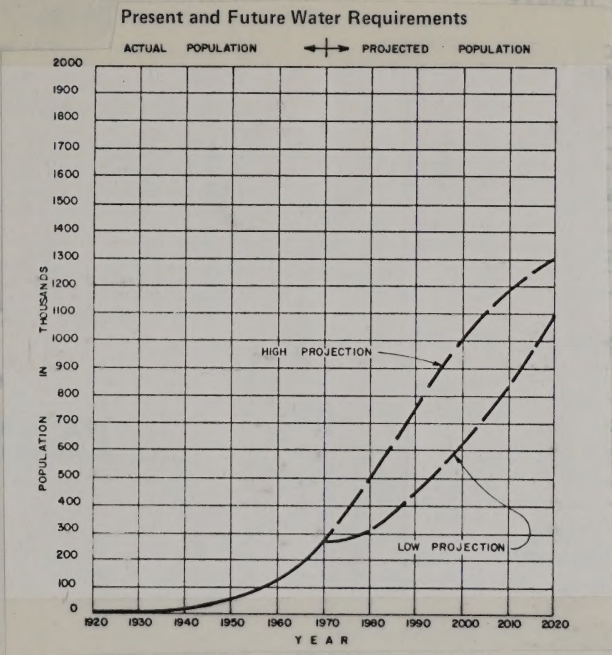


Figure 3 - Population Growth in Las Vegas Metropolitan Subarea

State Engineer, January, 1971

Figure 3 - Population Growth in Las Vegas Metropolitan Subarea

State Engineer, January, 1971

Year	Gross Water Demand AcFt/Yr	Ground Water AcFt/Yr	Lake Mead AcFt/Yr	Reclaimed Waste Water* AcFt/Yr	Total AcFt/Yr	Surplus or (Deficiency) AcFt/Yr
**						
1970	140,000					
1980	270,000	50,000	260,000	81,000	391,000	121,000
1990	392,000	50,000	258,000	118,000	426,000	34,000
2000	566,000	50,000	266,000	170,000	486,000	(80,000)
2010	662,000	50,000	281,000	199,000	530,000	(132,000)
2020	774,000	50,000	281,000	232,000	563,000	(211,000)
***						
1970	140,000					
1980	164,000	50,000	260,000	49,000	359,000	195,000
1990	249,000	50,000	258,000	75,000	383,000	134,000
2000	352,000	50,000	266,000	106,000	422,000	70,000
2010	490,000	50,000	281,000	147,000	478,000	(12,000)
2020	660,000	50,000	281,000	198,000	529,000	(131,000)

*Reclaimed waste water assumed to be 30% of gross water demand.
** Based on high growth rate.
*** Based on low growth rate.

TABLE II–7

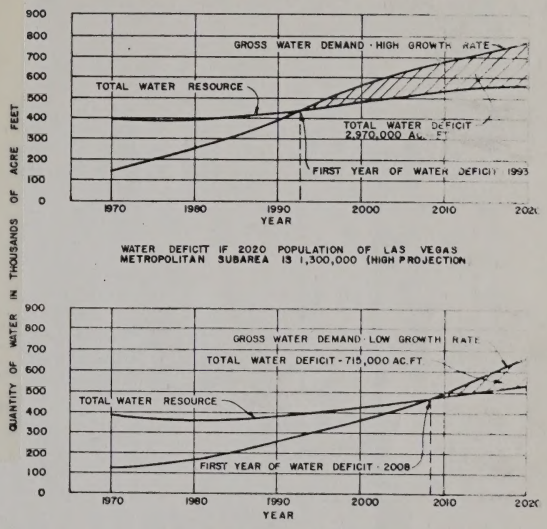
WATER SUPPLY AND DEMAND IN LAS VEGAS METROPOLITAN SUBAREA

Year	Maximum Water Requirement Ac. Ft. /Yr.	Minimum Water Requirement Ac. Ft. /Yr.
1970	140,000	140,000
1980	270,000	164,000
1990	392,000	249,000
2000	566,000	352,000
2010	662,000	490,000
2020	774,000	660,000

* Based on high and low projected rates of growth.

TABLE II–3

PROJECTED WATER REQUIREMENTS IN LAS VEGAS VALLEY METROPOLITAN SUBAREA


GROSS WATER DEMAND - HIGH GROWTH RATE
TOTAL WATER RESOURCE
TOTAL WATER DEFICIT 2,970,000 Ac. Ft.
FIRST YEAR OF WATER DEFICIT 1993
QUANTITY OF WATER IN THOUSANDS OF ACRE FEET
YEAR
WATER DEFICIT IF 2020 POPULATION OF LAS VEGAS METROPOLITAN SUBAREA IS 1,300,000 (HIGH PROJECTION
GROSS WATER DEMAND - LOW GROWTH RATE
TOTAL WATER DEFICIT - 715,000 AC.FT
TOTAL WATER RESOURCE
FIRST YEAR OF WATER DEFICIT - 2008
QUANTITY OF WATER IN THOUSANDS OF ACRE FEET
YEAR

(FIG. II-2) WATER DEFICIT IF 2020 POPULATION OF LAS VEGAS METROPOLITAN SUBAREA IS 1,100,000 (LOW PROJECTION

COMPONENTS OF TOTAL WATER RESOURCE

1. Withdrawal from Las Vegas Ground-Water Basin 50,000 Ac. Ft./Yr.
2. Nevada's entitlement of Colorado River water which is available for use in Las Vegas Metropolitan Subarea is approximately 281,000 Ac. Ft./Yr.
3. Quantity of reclaimed water is 0.3 times the gross water demand.

GROSS WATER DEMAND BASED ON;

1. Present daily per capita use of 475 gallons
2. Per capita water use will increase at the rate of 2.5 percent each 10 year period.

Table 8 - Waters Demands in Las Vegas Valley Metropolitan Subarea

State Engineer, January, 1971

Table 8 - Waters Demands in Las Vegas Valley Metropolitan Subares

State Engineer, January, 1971

TABLE 9 - EXISTING AND PROJECTED WATER REQUIREMENTS FOR LAS VEGAS VALLEY SUB-BASIN BASED ON LAND USE
(in acre feet per year)

	For Existing Population 311,000		For Projected Population 700,000	
	Per Capita Unit	Acre-feet	Per Capita Unit	Acre-feet
A. Potable Water				
1. Residential and Transient	0.303	94,200	0.318	222,600
2. Parks, Public Facilities	0.021	6,500	0.201	14,700
3. Golf Courses	0.0215	6,700	0.013	9,400
4. Agriculture	0.0125	3,900	0.0057	4,000
5. Industrial	0.054	16,900	0.0246	*17,200
6. Lt. Industrial & Commercial	0.021	6,500	0.023	16,300
7. Military	-0-	2,900	-0-	4,000
SUBTOTAL 'A'		137,600		288,200
B. Waste water				
1. Golf Courses	0.0045	1,400	0.0126	8,800
2. Agriculture	0.0161	5,000	0.0071	5,000
3. Industrial	-0-	-0-	0.0183	12,800
4. Power	-0-	3,200	-0-	4,000
5. Military (golf course)	-0-	-0-	-0-	500
SUBTOTAL 'B'		9,600		31,100
TOTAL 'A' and 'B'		147,200		319,300

* Includes flow from BMI system

TABLE 9 - EXISTING AND PROJECTED WATER REQUIREMENTS FOR LAS VEGAS VALLEY SUB-BASIN BASED ON LAND USE
(In acre feet per year)

		Per Capita Unit	For Existing Population 311,000	For Projected Population 700,000
A. Potable Water				
1. Residential and Transient		0.303	94,200	
2. Parks, Public Facilities		0.021	6,500	
3. Golf Courses		0.021S	6,700	
4. Agriculture		0.0125	3,900	
5. Industrial		0.054	16,800	
6. Lt. Industrial & Commercial		0.021	6,500	
7. Military		-0-	2,900	
SUBTOTAL 'A'			137,600	
B. Waste Water				
1. Golf Courses	0.0045		1,400	
2. Agriculture	0.0161		5,000	
3. Industrial	-0-		-0-	
4. Power	-0-		3,200	
5. Military (golf courses)	-0-		-0-	
	-0-		-0-	
SUBTOTAL 'B'			9,600	
TOTAL 'A' and 'B'			147,200	

* Includes flow from BMI system

Table 12.--Ground-water development and estimated average annual water consumption, 1966-67

Development location	Type development	Use	Estimated average use rate[1] (acre-feet per acre per year)	Acres	Crop	Estimated average annual consumption (acre-feet per year)
			MESQUITE VALLEY			
20/12-33d	well	irrigation	2.0	40	cotton	80
20/12-29d	well	irrigation	1.7	110	sorghum	190
20/12-34c, 19/12-11b	wells	irrigation	1.7	190	sorghum	320
19/12-2a	wells	irrigation	2.0	3	cotton	6
19/12-2a	wells	irrigation	3.3	40	alfalfa	130
19/12-22b	well	irrigation	3.3	40	alfalfa	130
19/12-22b	well	irrigation	2.0	10	cotton	20
19/12-16a	wells	irrigation	3.3	160	alfalfa	530
Throughout valley	wells	domestic	Est. 0.1 acre-foot per person annually (30 people)	--	--	3
Throughout valley	wells	livestock	Est. 15 gpd per head (est. 100-200 head)	--	--	2
Total (rounded)				600		1,400
			IVANPAH VALLEY (Nevada part)			
T. 24 S., R. 58 E.	Goodsprings wells	Goodsprings domestic and public supply	Est. 0.1 acre-foot per person annually (100 people)	--	--	10
T. 25 S., R. 59 E.	Jean wells	Jean domestic and public supply	Est. based on transient population (65 people) and pumpage rates (25,000-40,000 gpd)[2]	--	--	20
Throughout valley	wells	livestock	Est. 6 gpd per head (est. 100-200 head)	--	--	1
Total (rounded)				--	--	30

1. Crop use rate based on those developed by houston, 1950.
2. Reported by Jean Water Manager

Table 11

Public Health Standards Drinking Water

Substance	Concentration in mg/l
Alkyl Benzene Sulfonate (ABS)	0.5
Arsenic (AS)	0.01
Chloride (Cl)	250.
Copper (Cu)	1.0
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Floride (F)	0.3
Manganese (Mn)	0.05
Nitrate (No_3)	45.
Phenols	0.001
Sulfate (SO_4)	250.0
Total Dissolved Solids	500.0
Zinc (Zn)	5.0

The above chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the reporting agency and the certifying authority, other more suitable supplies are or can be available.

The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply.

Substance	Concentration in mg/l
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hdrovalent) (Cr^{+6})	0.05
Cyanide (CN)	0.2
Floride (F)	See Table 1
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

Table II

Public Health Standards Drinking Water

Substance	Concentration in mg/l
Alkyl Benzene Sulfonate (ABS)	0.5
Arsenic (As)	0.01
Chloride (Cl)	250.
Copper (Cu)	1.0
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Fluoride (F)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45.
Phenols	0.001
Sulfate (SO_4)	250.0
Total Dissolved Solids	500.0
Zinc (Zn)	5.0

The above chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the reporting agency and the certifying authority, other more suitable supplies are or can be available.

The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply.

Substance	Concentration in mg/l
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hexavalent) (Cr^{+6})	0.05
Cyanide (CN)	0.2
Fluride (F)	See Table I
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

TABLE III 12

PHYSICAL AND CHEMICAL QUALITY
OF SURFACE AND GROUNDWATER SUPPLIES IN PROJECT AREA

(All values except pH in milligrams per liter)

Source	Date	Temp. °C	pH	Cl	Alk.	SO_4	Fe	F	Total Hdn.	TDS
Colorado River near Boulder City 1/	Water Year 1961	12.5-17.0	7.8-8.3	70-88	108-134	210-243	0.00-0.01	0.2-0.3	320-348	675-711
Las Vegas 2/	11/2/51	-	7.6	3.9	236	46	0.10	0.3	229	266
North Las Vegas 2/	3/29/51	21.1	7.6	3.2	226	33	0.02	0.1	206	235
Nellis Air Force Base, composite of ten wells 3/	undated	-	8.1	18	227	92	-	0.7	221	476

1/ Department of Health, Education, and Welfare, National Water Quality Network, unpublished data for 1961 water year; except Fe and F data from USGS W.S.P. 1523, pp. 181-182.

2/ U. S. Geological Survey, Water Supply Paper 1300. Reservoir composites of groundwater supplies.

3/ U. S. Bureau of Reclamation, Region 3, unpublished data.

Udall, Dominy & West

Concentrations, mg/l (except pH)

	Constituent	USPHS & Nevada Standards	24-yr Avg. Lake Mead Diversion at Boulder City Intake 1935-1958*	24-yr Avg. Lake Mead Diversion at Boulder City Intake 1941-1964**	BMI Pipeline at Booster Station No. 2 Feb. 1967
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5			
	Arsenic	0.01			
	Chloride (Cl)	250.0	75	75	91
	Copper (Cu)	1			
	Carbon Chloroform Extract (CCE)	0.2			
	Cyanide (CN)	0.01			
	Fluoride (F)	(See Table II-4)	1		
	Iron (Fe)	0.3			0.03
	Manganese (Mn)	0.05			
	Nitrate (NO_3)	45.0	2		4.25
	Phenols	0.001			
	Sulfate (SO_4)	250	288	288	312
	Total Dissolved Solids	500	688	684	742
	Zinc (Zn)	5			
Mandatory	Arsenic (As)	0.05			
	Barium (Ba)	1.0			
	Cadmium (Cd)	0.01			
	Chromium (Hexavalent) (Cr^{+6})	0.05			
	Cyanide (CN)	0.2			
	Fluoride (F)	(See Table II-4)	1		
	Lead (Pb)	0.05			
	Selenium (Se)	0.01			
	Silver (Ag)	0.05			
No Limits Given	Alkalinity ($CaCO_3$)				122
	Bicarbonate (HCO_3)		186	161	149
	Carbonate (CO_3)				0
	Total Hardness ($CaCO_3$)		328		336
	Calcium (Ca)		92	91	84.8
	Magnesium (Mg)		30	26	30.08
	Sodium (Na)		92	91	111.64
	Sodium and Potassium (Na+K)		96		8.07
	pH				

Source * Report on SNWP, Nevada Appendices Vol II August 1963 by U. S. Bureau of Reclamation

** Quality of water Colorado River Basin, Progress Report No. 3 January 1967 by U. S. Dept. of Interior

Table 13 - Chemical Analysis - Lake Mead

State Engineer, 1971

Table 13 - Chemical Analysis - Lake Mead

State Engineer, 1971

TABLE 4

Analyses of Water from Wells and Springs in Las Vegas, Pahrump, and Indian Spring Valleys, Nevada

(Analyses by M. R. Miller, University of Nevada, Agricultural Experiment Station, or W. B. Adams, Public Service Division, University of Nevada, Department of Food and Drugs, except as noted. Carbonate 0.00 when determined. See tables 2 and 3 for descriptive data for wells.)

Well or spring number and location	Owner or name of well or spring	Depth (feet)	Temperature (°F)	Date of collection	Parts Per Million: Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na and K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness (as $CaCO_3$)
				INDIAN SPRING VALLEY											
(S-16-56) 16b1	Indian Springs	----	78	12-15-12	330	17	0.16	48	15	31	239	28	5	0.0	181
				LAS VEGAS VALLEY											
(S-17-59) 34a1[1]	Corn Creek Spring	----	----	12- 8-12	287	18	.03	54	28	17	292	26	12	4	250
(S-19-60) 9c1[2]	Tule Springs	----	69.5	4-20-29	207	----	----	52	28	1.9	255	27	8.6	----	----
(S-20-61) 15dc1[1]	Kyle Spring	----	76	9-16-12	258	8	.01	53	27	26	251	33	55	2	243
(S-20-61) 19abd1[3]	Splane Estate	260	69	1- 6-47	238	----	----	51	25	4.6	242	33	4	1.2	230
(S-20-61) 30ddc1	Las Vegas Springs	----	73	9-23-12	267	13	Tr.	56	23	17	239	43	2	6	234
(S-20-61) 30ddd1[1]															
(S-20-61) 31aab1															
(S-21-61) 6acc1[4]	J. D. Porter	394	72	1- 6-47	290	----	----	54	29	11	231	71	5	3.5	251
(S-21-61) 22ccc1[5]	A. P. Baker	500	72	1- 6-47	334	----	----	65	32	7.8	227	106	7	4.3	294
(S-21-61) 34abc1[6]	Tollackson	246	74	1- 6-47	332	----	----	64	30	11	223	107	6	3.9	283
(S-21-62) 29db1[1]	Grapevine Spring	----	----	12-24-12	2012	55	.3	275	130	99	239	959	172	.3	1220
(S-22-59) 7c1[1]	Cottonwood Spring	----	----	9-18-12	563	19	.4	102	43	46	290	146	11	.45	431
				PAHRUMP VALLEY											
(S-20-52) 1c1[2]	Buol Sixmile Spring	----	----	8- 5-27	538	----	----	73	18	40	365	36	6.2	----	----
(S-20-53) 14dc1[2]	Bennetts Springs	----	76.5	8- 5-27	358	----	----	50	22	8.2	244	33	.7	----	----
(S-20-53) 14dcc1[7]	Ray Thomas	254	78	8-29-16	383	8	Tr.	51	25	42	242	32	63	Tr.	230
(S-20-53) 15adc1[2]	Frank Buol	520	----	8- 5-27	391	----	----	54	17	21	268	30	.7	----	----
(S-20-56) 31d1[7]	Intermittent Spring	----	57	8-24-16	251	10	.0	59	24	4.3	273	22	5	1.5	246
(S-21-54) 3bc1[7]	Manse Spring	----	75	8-27-16	268	18	Tr.	55	29	Tr.	239	42	4.9	.0	256
(S-21-54) 3bc1[2]	Manse Spring	----	75	8- 5-27	375	----	----	52	11	30	239	42	.7	----	----
(S-22-54) 11d1[2]	Steve Brown Spring	----	----	8- 5-27	406	----	----	73	13	.0	269	51	.5	----	----
(S-22-54) 25b1[7]	Roland Wiley	26	----	8-27-16	338	13	.45	58	30	20	266	58	24	.0	----

[1]Taken from Carpenter, Everett, Ground water in southeastern Nevada: U. S. Geol. Survey Water-Supply Paper 365, table facing p. 30, 915.
[2]Taken from Hardman, George, and Miller, M. R., Quality of the waters of southeastern Nevada, drainage basins and water resources: Univ. of Nevada Agri. Exper. Sta. Bull. No. 136, pp. 24–32, July 1934.
[3]By C. S. Howard, U. S. Geol. Survey, specific conductance 43.5, carbonate not determined, fluoride 0.2.
[4]By C. S. Howard, U. S. Geol. Survey, specific conductance 50.1, carbonate not determined, fluoride 0.2.
[5]By C. S. Howard, U. S. Geol. Survey, specific conductance 56.0, carbonate not determined, fluoride 0.1.
[6]By C. S. Howard, U. S. Geol. Survey, specific conductance 56.4, carbonate not determined, fluoride 0.3.
[7]Taken from Waring, G. A., Ground water in Pahrump, Mesquite, and Ivanpah Valleys, Nevada and California: U. S. Geol. Survey Water-Supply Paper 450C, table facing p. 80, 1921.

Markey & Jameson

TABLE VI 15
QUALITY AND FLOWS 1/
LAS VEGAS WASH AND TRIBUTARY WASTEWATERS

Stream	Type of Water	Estimated Annual Discharge Acre-feet	Quality in ppm								
			pH	Ca+Mg	Na+K	HCO_3	Cl	SO_4	Fe	F	Hdns	TDS
Las Vegas Sewage Plant	Municipal Sewage	11,000	7.6	97	827(?)	398	106	230	0.3	3.3	312	634
So. Nevada Power Co.	Cooling & blowdown	1,100	7.4	250	206	102	473	1100	0.9	2.3	756	2414
Henderson Industries	Chemical & metallurgical waste waters	8,500	2.0	153	3060	-	4023	1338	-	1.2	440	7858
Las Vegas Wash	Natural stream below waste-water discharges	15,000	8.0	1008	1160	373	1973	2375	-	1.4	3080	7242

1/ Water analysis from samples taken May 4, 1962, by U. S. Bureau of Reclamation. Estimates of flow from Leeds, Hill & Jewett report, Reference (6).

Table 16

Chemical Analysis* Las Vegas Valley

Average Concentration of Chemical Constituents and Average Temperature in the Shallow, Middle, and Deep Zones of Aquifers in Three Areas in Las Vegas Valley.

Zone of aquifers	Number of samples	Total solids	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na and K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Hardness	Percent Sodium (Na)	Temperature, °F.
Vicinity of Las Vegas and Tule Springs												
Shallow	26	322	18[1]	50	22	14	228	41	8	211	22	71[2]
Middle	11	328	...	45	25	8	225	32	7	215	8	72[4]
Deep	8	294	18[3]	39	20	26	206	45	7	180	24	75[4]
Paradise Valley												
Shallow	16	714	24[5]	120	44	24	204	315	28	481	10	79[6]
Middle	2	775	...	131	44	25	175	375	29	512	10	
Deep	1	580	36	79	39	33	195	232	20	357	18	
Vicinity of Whitney, Pittman, and Winterwood Ranch												
Shallow	6	2,922	59[7]	244	121	455	125	1,383	443	1,097	47	
Middle	7	3,122	50	240	89	602	115	1,678	303	963	58	76[8]
Deep	2	2,170	...	91	14	589	122	1,161	184	287	81	

[1]Average of 9 samples. [2]Average of 16 samples. [3]Average of 3 samples.
[4]Average of 6 samples. [5]Average of 8 samples. [6]Average of 10 samples.
[7]Average of 4 samples. [8]Average of 2 samples.

* Concentrations are in ppm

Maxey and Jameson, 1948

Table 16

Chemical Analysis* Las Vegas Valley

* Concentrations are in ppm

Maxey and Jameson, 1948

TABLE 17 - CHEMICAL ANALYSIS* OF WELL WATER LAS VEGAS VALLEY

AREAS	Blue Diamond			Henderson			Mt. Charleston					Indian Springs AAFB		Nellis AFB No. 2		
WELLS	Arden	Rainbow Canyon	Red Rock	#2, 1964	#2, 1964	Section 20 1965	Lee Canyon Well	Lee Canyon Spring	USFS	Community	Kyle Canyon	#2	#1	Well #3	Well #4	Well #5
TDS	557	599	467	1068	1268	668	188	164	241	266	203	620	301	514	497	253
Alkalinity	192	216	284	-	-	138	-	166	208	262	194	188	212	188	165	190
Bicarbonate	234	264	346	-	-	167	205	203	254	320	237	229	259	229	201	232
Hardness	430	444	370	-	-	420	180	176	224	272	208	440	250	300	220	180
Calcium	85	98	78	-	-	158	46	45	66	64	62	93	53	39	39	29
Magnesium	53	48	42	-	-	6	16	16	17	27	13	50	29	49	31	25
Sulfate	230	207	99	588	619	260	T	19	19	12	4	240	48	160	150	26
Chloride	11	10	1	-	-	121	1	5	2	3	4	63	12	27	44	7
Nitrate	1	2	1	-	-	6	0	0	1	1	2	3	1	2	1	1
Sodium & Potassium	8	1	9	-	-	119	T	8	4	3	1	43	9	42	73	20

Source: Nevada State Health Division, Las Vegas, Nevada

* all concentrations in mg/l

Necon, 1973

TABLE 17 - CHEMICAL ANALYSIS* OF WELL WATER LAS VEGAS VALLEY

AREAS	Blue Diamond			Henderson			MtMtCharleston					Indian Springs AAFB		Nellis AFB No. 2		
WELLS	Arden	Bridge Canyon	Red Rock	4961 '2"	4961 '2"	02 Section 5961	11M Red Canyon	Bridge Canyon	SSD	Community	Kyle Canyon	2#	1#	3# 11M	4# 11M	5# 11M
TDS	557	599	467	1068	1268	668	188	164	241	266	203	620	301	514	497	253
Alkalinity	192	216	284	-	-	138	-	166	208	262	194	188	212	188	165	190
Bicarbonate	234	264	346	-	-	167	205	203	254	320	237	229	259	229	201	232
Hardness	430	444	370	-	-	420	180	176	224	272	208	440	250	300	220	180
Calcium	85	98	78	-	-	158	46	45	66	64	62	93	53	39	39	29
Magnesium	53	48	42	-	-	6	16	16	17	27	13	50	29	49	31	25
Sulfate	230	207	99	588	619	260	T	199	19	12	4	240	48	160	150	26
Chloride	11	10	1	-	-	121	1	5	2	3	4	63	12	27	44	7
Nitrate	1	2	1	-	-	6	0	0	1	1	2	3	1	2	11	1
Sodium & Potassium	8	1	9	-	-	119	T	8	4	3	1	43	9	42	73	20

Source: Nevada State Health Division, Las Vegas, Nevada

* all concentrations in mg/l

Necon, 1973

Table 18

Table 15.--Chemical analyses of water from selected wells

[Field-office analyses by the U.S. Geological Survey, except where noted]

Salinity and alkalinity hazards: L, low; M, medium; H, high; V, very high

RSC: S, safe; M, marginal

Location	Date sampled	Temperature (°F)	Parts per million (upper number), equivalents per million (lower number)												Hardness as $CaCO_3$		Specific conductance (micromhos per cm at 25°C)	pH	Irrigation quality[2]		
			Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Sodium (Na) plus Potassium (K)[1]	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Calcium, magnesium	Noncarbonate			Salinity hazard	Alkalinity hazard	RSC
MESQUITE VALLEY																					
18/13-8Q1[3]	5- 7-54	66	149 7.46	99 8.13	322 14.00	19 0.50	-- --	316 5.18	0 0.00	364 7.60	615 17.34	3 0.05	1.6 0.08	0.35 --	780	521	2,940	7.6	V	L	S
19/12-2A1	1-22-67	--	60 2.99	42 3.42	-- --	-- --	21 0.90	252 4.13	0 0.00	138 2.87	11 0.31	-- --	-- --	-- --	321	114	638	8.1	M	L	S
19/12-2D1[3]	5-20-55	61	68 3.39	40 3.29	19 0.82	2.5 0.82	-- --	234 3.84	0 0.00	161 3.35	14 0.39	4 0.06	0.6 0.03	0.04 --	334	142	648	7.6	M	L	S
19/12-3B1[3]	5-20-55	61	66 3.29	45 2.70	24 1.40	4.3 0.11	-- --	290 4.76	0 0.00	139 2.89	10 0.28	5 0.07	0.4 0.02	0.16 --	350	112	714	7.4	M	L	S
19/12-4B1[3]	5-20-55	66	53 2.64	45 3.70	20 0.87	1.8 0.05	-- --	261 4.28	0 0.00	121 2.53	8 0.23	6 0.09	0.4 0.02	0.12 --	317	103	588	7.8	M	L	S
19/12-11D1[3]	5-20-55	66	56 2.79	40 3.29	14 0.61	2.3 0.06	-- --	229 3.76	0 0.00	124 2.58	9 0.25	3 0.04	0.5 0.03	0.10 --	304	116	568	8.0	M	L	S
19/12-11Q1[3]	5- 7-54	66	51 2.54	51 4.26	20 0.88	2.5 0.06	-- --	276 4.54	0 0.00	132 2.75	12 0.34	4 0.07	0.7 0.04	0.15 --	335	108	617	7.9	M	L	S
19/12-14D1[3]	5- 7-54	68	58 2.90	80 6.64	36 1.58	2.5 0.06	-- --	252 4.14	0 0.00	308 6.42	21 0.59	7 0.11	0.7 0.04	0.3 --	427	220	953	8.0	H	L	S
19/12-14E1[3]	5-20-55	54	36 1.80	48 3.95	112 4.87	3.6 0.09	-- --	232 3.80	0 0.00	130 2.70	151 4.26	0 0	0.6 0.03	0.24 --	288	98	998	7.6	H	L	S
19/12-14M1[3]	5-20-55	--	41 2.05	60 4.93	140 6.08	4.0 0.10	-- --	178 2.92	24 0.80	160 3.33	230 6.49	3 0.05	0.6 0.03	0.2 --	348	162	1,360	8.5	H	L	S
19/12-15R1	1-22-67	65	33 1.65	51 4.20	-- --	-- --	51 2.20	382 6.26	0 0.00	40 0.83	34 0.96	-- --	-- --	-- --	293	0	722	7.7	M	L	S
19/12-26H1[3]	9-11-53	--	84 4.19	74 6.08	240 10.44	10 0.24	-- --	234 3.84	0 0.00	466 9.71	254 7.16	3 0.05	1.2 0.06	0.44 --	508	316	1,950	8.0	H	L	S
19/12-26H2	1-22-67	--	59 2.94	49 4.01	-- --	-- --	127 5.51	252 4.13	0 0.00	194 4.04	152 4.29	-- --	-- --	-- --	348	141	1,220	8.0	H	L	S
19/13-19N1[3]	9-14-54	63	18 0.90	28 2.35	521 22.65	62 1.59	-- --	284 4.65	0 0.00	260 5.42	593 16.73	8 0.13	1.2 0.06	0.23 --	163	0	2,500	8.0	V	H	M
20/12-19F1[3]	9-14-54	68	61 3.05	37 3.10	18 0.77	2 0.05	-- --	214 3.51	0 0.00	128 2.66	17 0.48	22 0.35	0.1 0.01	0.15 --	307	131	565	8.0	M	L	S
20/12-33Q1[3]	9-14-54	68	48 2.40	37 3.10	19 0.82	1.8 0.05	-- --	238 3.90	0 0.00	89 1.85	7 0.20	4 0.07	0.1 0.01	0.10 --	275	80	511	7.8	M	L	S
24/58-26b1	1-21-67	62	58 2.89	30 2.44	-- --	-- --	-- --	236 3.87	0 0.00	-- --	30 0.85	-- --	-- --	-- --	267	73	611	--	M	--	S
25/57-5a1[3]	9-14-54	68	79 3.95	40 3.34	14 0.63	2 0.05	-- --	269 4.41	0 0.00	138 2.87	18 0.51	5 0.08	0.2 0.01	0.16 --	365	144	637	7.8	--	L	S
25/57-9a1	1-22-67	--	64 3.19	42 3.48	-- --	-- --	20 0.88	280 4.59	0 0.00	111 2.31	23 0.65	-- --	-- --	-- --	334	104	667	8.1	M	L	S
25/57-36b1	1-22-67	63	62 3.09	36 2.98	-- --	-- --	-- --	276 4.52	0 0.00	-- --	334 9.70	-- --	-- --	-- --	304	78	1,840	--	H	--	S
IVANPAH VALLEY																					
15½/15-20J1[3]	5- 8-54	75	24 1.22	9 0.76	129 5.60	8 0.20	-- --	109 1.79	0 0.00	38 0.80	175 4.92	6 0.10	2.0 0.11	0.25 --	89	0	845	8.1	H	L	S
15½/15-23N1[3]	9-14-54	68	28 1.40	22 1.83	43 1.86	5.5 0.14	-- --	189 3.10	0 0.00	39 0.81	28 0.78	10 0.16	1.0 0.05	0.20 --	161	6	464	7.3	M	L	S
16/14-1H1[3]	9-11-53	72	42 2.10	19 1.56	60 2.61	3.0 0.08	-- --	194 3.20	0 0.00	44 0.92	67 1.89	15 0.24	0.3 0.02	0.16 --	187	27	641	7.8	M	M	S
16/14-12Q1[3]	5- 8-54	--	25 1.26	19 1.60	83 3.60	4.7 0.12	-- --	156 2.56	0 0.00	38 0.79	96 2.71	19 0.31	1.4 0.07	0.20 --	143	15	643	7.9	M	L	S
16/14-23Q1[3]	5- 8-54	--	45 2.25	31 2.53	71 3.10	4 0.10	-- --	136 2.68	0 0.00	76 1.58	121 3.42	17 0.27	0.9 0.05	0.25 --	237	103	794	7.6	H	L	S
16/16-33L1[3]	5- 8-54	78	8 0.40	1.1 0.09	105 4.58	2.5 0.06	-- --	131 2.15	0 0.00	41 0.86	65 1.83	19 0.30	2.1 0.11	0.20 --	25	0	528	8.2	M	M	M
17/14-36M1[3]	5-21-55	--	99 4.94	28 2.30	4,600 200.1	45 1.15	-- --	134 2.20	7 0.24	629 13.11	6,800 191.8	0 0.00	2.3 0.12	3.8 --	312	190	19,200	8.2	V	V	S
27/59-8a1[3]	5-21-55	72	583 29.1	0 0	5,000 217.5	105 2.69	-- --	20 0.32	12 0.40	1,060 22.07	7,800 220.0	13 0.21	1.0 0.05	2.3 --	143	107	19,200	9.0	V	V	S
JEAN LAKE VALLEY																					
25/60-10d1	5-21-55	--	30 1.50	30 2.46	-- --	-- --	175 7.60	136 2.23	0 0.00	88 1.83	266 7.50	-- --	-- --	-- --	198	87	1,300	7.7	H	L	S

1. Computed by arithmetic difference, and reported as sodium.
2. Classification based on criteria stated by U.S. Salinity Laboratory Staff (1954, p. 75-82).
3. Analytical data from California Department of Water Resources (1956, p. 24-29).

Glancy, 1968

	Constituent	USPHS & Nev. Standards	Concentrations mg/l (except pH) Wells					
			19-53-9bb	19-53-21aa	20-53-3cd	21-54-16ad	21-54-21bc	22-54-24dc
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5						
	Arsenic (As)	0.01						
	Chloride (Cl)	250	12.0	6.0	3.8	3.0	2.8	6.0
	Copper (Cu)	1						
	Carbon Chloroform Extract (CCE)	0.2						
	Cyanide (CN)	0.01						
	Fluoride (F)	(See Table II-4)	0.3	0.1	0.2	0.5	0.2	0.4
	Iron (Fe)	0.3						
	Manganese (Mn)	0.05						
	Nitrate (NO_3)	45	2.4	2.0	1.7	0.6	0.9	0.5
	Phenols	0.001						
	Sulfate (SO_4)	250	36.0	20.0	26.0	47.0	48.0	55.0
	Total Dissolved Solids	500	314.0	264.0	249.0	260.0	234.0	324.0
	Zinc (Zn)	5						
Mandatory	Arsenic (As)	0.05						
	Barium (Ba)	1.0						
	Cadmium (Cd)	0.01						
	Chromium (Hexavalent) (CR^{+6})	0.05						
	Cyanide (CN)	0.2						
	Fluoride (F)	(See Table II-4)						
	Lead (Pb)	0.05						
	Selenium (Se)	0.01						
	Silver (Ag)	0.05						
No Limits Given	Alkalinity ($CaCO_3$)		280.0	269.0	242.0	224.0	186.0	281.0
	Bicarbonate (HCO_3)		222.0	232.0	215.0	223.0	188.0	-
	Total Hardness ($CaCO_3$)		46.0	47.0	50.0	53.0	36.0	69.0
	Calcium (Ca)		26.0	28.0	22.0	22.0	24.0	26.0
	Magnesium (Mg)		28.0	7.5	6.9	7.1	9.2	6.9
	Sodium (Na)		32.0	9.1	9.1	7.9	10.7	7.3
	Sodium and Potassium (Na+K)		7.8	7.9	8.1	7.8	7.7	8.0
	pH							
	Carbonate (CO_3)							

Source: Geological Survey Water Supply Paper 1832 Page 141.

Table 19 - Chemical Analysis of Well Water—Pahrump

Table 19 - Chemical Analysis of Well Water--Fairmont

Table 20

Chemical Analysis of Well Water - Jean, Goodsprings - 1968 - 1971

	JEAN				GOODSPRINGS		
	1. Well	2. Well	Rest Area	Tower Club	Elementary School	Pioneer	School
Total Dissolved Solids	2170	1551	1615	415	540	673	655
Alkalinity	192	124	76	180	240	252	232
Bicarbonate	234	151	93	220	293	307	283
Hardness	48	636	640	48	388	450	380
Calcium	5	102	130	6	74	75	66
Magnesium	9	91	77	7	50	64	53
Sulfate	221	60	170	34	120	163	100
Chloride	850	810	700	80	49	55	22
Nitrate	11	1	11	14	9	20	17
Sodium Plus Potassium	727	325	282	17	25	30	0
Fluoride	3.5	-	-	0.6	0.5	0.3	0.3

Source: Nevada State Health Division, Las Vegas, Nevada

Necon, 1973

Table 20

Chemical Analysis of Well Water - Jean, Goodspring - 1968 - 1971

Recon, 1973

Table 21

Chemical Analysis of Well Water in Nelson

Chemical Substance	Concentration (ppm)
Total dissolved solids	586
Alkalinity	166
Bicarbonate	203
Carbonate	0
Total Iron	0.01
Total hardness ($CaCo_3$)	372
Ca	99
Magnesium	59
Sulfate	146
Chloride	74
Nitrate	12.8
Sodium and Potassium	33
Arsenic	Neg
Floride	0.62

Table 21

Chemical Analysis of Well Water in Nelson

Chemical Substance	Concentration (ppm)
Total dissolved solids	586
Alkalinity	166
Bicarbonate	203
Carbonate	0
Total Iron	0.01
Total hardness ($CaCO_3$)	372
Ca	99
Magnesium	59
Sulfate	146
Chloride	74
Nitrate	12.8
Sodium and Potassium	33
Arsenic	Neg
Floride	0.62

Table 22 - Chemical Analysis - Amargosa Desert - concentrations are in ppm

Location	Date of collection	Depth of well (feet)	Temperature (°F)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium	Hardness as $CaCO_3$: Magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent Na	SAR	RSC	Irrigation class	Specific conductance (micromhos at 25°C)	pH	Color
13S/51-20d1	9-18-57	1,327	92	67	0.1	0.26	85.0	14.0	0.0	157	16.0	--	102	0	484	20.0	0.9	7.4	0.0	--	893	270	186	54	4.4	0.0	C3-S1	1,210	7.8	3
14S/50- 6a1	4-25-58	887	78	26	.2	.52	9.6	1.9	--	46	5.2	--	121	0	24	7.0	1.8	.0	.0	--	169	32	0	72	4.1	1.45	C2-S1	266	8.2	1
15S/49-14a1	4-24-58	570	82	52	.1	.09	25	2.4	--	41	5.2	--	145	0	33	8.0	1.4	3.5	.0	--	233	72	0	53	2.25	.93	C2-S1	336	8.0	0
15S/50-18c1	5- 8-52	395	--	36	--	1.50	16	2.4	--	119	4.2	--	166	0	124	25	1.9	6.5	--	.29	417	50	0	82	7.47	1.72	C2-S2	629	7.9	-
15S/50-18c5	6-26-59	360	75	45	.0	.67	21	2.9	<.2	103	6.0	--	162	0	122	18	1.4	6.9	.0	--	408	64	0	76	5.78	1.37	C3-S1	863	7.9	0
16S/48-15a1	5-24-56	150	--	76	--	.22	12	3.2	--	65	3.2	0	166	0	30	8.0	3.0	4.1	--	.09	--	43	0	--	4.43	1.86	C2-S1	381	7.7	5
16S/48-17a1	8-18-62	280	75	75	.0	.00	60	7.8	.6	157	12	.20	302	0	179	69	1.2	1.2	.0	.57	800	182	0	--	5.06	1.32	C3-S1	1,074	7.4	-
16S/48-23b1	8-19-62	330	75	74	.57	1.1	9.4	1.0	1.8	66	6.8	.06	156	0	27	8.8	2.0	3.1	.0	.15	294	30	0	--	5.32	1.93	C2-S1	346	7.3	-
16S/48-36a1	2-21-56	165	74	82	.2	.14	70	3.9	--	62	9.0	--	142	0	107	61	1.4	17	.0	--	489	190	74	40	2.13	.0	C2-S1	700	7.9	0
16S/48-36d1	8-18-62	407	--	74	.22	.03	40	8.6	.7	98	11	.10	278	0	43	29	2.8	7.8	.0	.28	506	137	0	--	3.14	1.83	C2-S1	670	7.6	-
16S/49- 9c1	8-19-62	300	75	56	.30	.00	28	3.4	.9	46	7.6	.06	142	0	53	10	.7	3.3	.0	.16	310	85	0	--	2.17	.63	C2-S1	381	7.2	-
16S/49-35b1	8-18-62	325	76	34	.60	.03	50	17	1.0	106	12	.18	286	0	145	29	4.4	.5	.0	.42	545	196	0	--	3.38	.79	C3-S1	796	7.3	-
16S/50- 7c1	8-18-62	200	--	31	.29	.88	51	18	1.2	103	13	.14	288	0	143	30	4.0	.7	.0	.36	581	203	0	--	3.13	.70	C3-S1	821	7.7	-
16S/53- 4b1	7-10-62	1,953	92	21	.03	.03	47	21	.40	37	5.2	0	256	0	53	16	.9	1.2	.16	--	330	204	0	--	1.2	.12	C2-S1	544	7.1	-
17S/49-35d1 Ash tree Spring	5- 8-52	--	74	80	--	.08	16	4.8	--	55	7.9	--	160	0	37	7.2	2.8	3.9	--	.29	293	60	0	63	3.35	1.43	C2-S1	370	7.9	-
17S/50-15a1	8-18-62	464.6	67	23	.12	.16	50	20	.8	67	9.2	.10	305	0	79	23	1.2	.9	.0	.28	447	209	0	--	2.02	.75	C2-S1	665	7.6	-
17S/50-29d1	8-18-62	470.7	67	67	.00	.10	2.8	2.9	7.7	250	15	.14	494	0	105	26	3.2	.0	.0	1.4	733	28	0	--	27.6	7.72	C3-S4	1,067	7.6	-
17S/50-36d1 Devils Hole	1-22-53	--	92	23	--	.04	51	21	--	66	7.2	--	311	0	79	22	1.6	.5	--	.38	425	214	0	39	2.08	.83	C2-S1	686	7.4	-
17S/51- 1a1	1-10-61	135	73	18	.2	.00	39	20	--	69	10	--	350	0	53	6.0	.6	.0	.32	--	372	180	0	--	2.43	1.79	C2-S1	607	7.2	1
17S/52- 8c1	4-27-58	--	82	18	.2	.00	34	22	--	61	7.2	--	274	0	63	21	1.1	.0	.0	--	342	176	0	42	2.14	.98	C2-S1	595	8.0	0
18S/50- 5d1 Carson Slough	1-27-59	--	50	28	.2	.21	40	26	1.8	125	16	--	362	10	122	40	2	.0	.07	.68	566	207	0	54	4.05	2.12	C3-S1	937	8.5	0
18S/51- 7c1 King Spring	2-28-49	--	89	23	--	.02	49	21	--	69	7.7	--	310	0	80	21	1.4	.4	--	.1	425	209	0	--	2.21	.91	C2-S1	680	7.2	-
18S/51-19a Big Spring	1-27-59	--	83	32	.0	.11	45	18	1.8	98	8.8	--	314	0	110	25	1.4	.3	.08	.51	468	186	0	52	3.5	1.88	C3-S1	780	7.7	0
18S/51-30a Bole Spring	7-27-62	--	72	33	.11	.03	38	19	.60	106	9.2	.17	306	0	113	27	1.0	1.0	.0	--	500	173	0	--	3.7	1.56	C3-S1	776	7.1	-
25N/5-14c1	8-29-52	146	--	31	--	.06	1.9	1.9	--	325	12	--	556	43	149	49	7.9	.2	--	1.3	874	12	0	96	37.9	9.57	C3-S4+	1,380	8.6	-
25N/6-18a1	8-18-62	27.5	67	64	.12	.10	4.8	3.3	.5	370	16	.30	542	0	256	102	3.2	.5	.0	2.8	1,119	26	0	--	31.6	8.37	C4-S4+	3,241	7.9	-
25N/6-20c1	8-18-62	8.1	68	28	.43	.03	1.2	1.4	4.2	1,060	88	.10	712	64	297	1,050	7.0	.2	.32	.2	2,891	223	0	--	123	13.6	C4-S4+	4,730	8.6	-
27N/4-27b2	8-18-62	300	72	72	.14	.10	58	19	.6	134	19	.14	438	0	107	32	3.6	--	.0	.4	640	--	0	--	3.90	2.73	C3-S1	943	7.8	-

Walker and Eakin, 1963

mag ci era architettura - corso di laurea magistrale - progetto urbano - a.a. 2018

Table 23 - Economization of Water

GROSS WATER DEMAND FORCAST AND POSSIBLE ECONOMIES

Land Use	Water Consumption Forecast* MGD 1970	Water Consumption Forecast* MGD 2000**	Low Population Projection Water Consumption Without Economization 2020 MGD	Low Population Projection Water Consumption With Economization 2020 MGD	High Population Projection Water Consumption Without Economization 2020 MGD	High Population Projection Water Consumption With Economization 2020 MGD
Rural	5.1	15.4	20.9	14.9	24.5	17.5
Suburban Residential	4.8	19.6	26.6	16.6	31.2	16.2
Low Density Residential	46.6	156.9	213.0	124.2	250.0	90.5
Medium Density Residential	4.7	20.6	28.0	43.0	32.8	53.9
High Density Residential	12.9	24.2	32.9	32.9	38.6	38.6
High Rise Hotel-Casino Motel-Hotel	12.1	25.9	35.2	31.7	41.3	37.2
Agriculture	5.2	25.4	34.5	14.5	40.5	10.5
Highway Oriented	5.0	10.9	14.8	13.3	17.5	15.6
Light Industrial	6.7	30.4	41.4	37.3	48.4	40.4
General Industrial	14.5	48.1	65.3	52.3	76.6	62.6
Military and Airport	1.7	6.4	8.7	7.6	10.2	9.2
Parks	5.0	49.8	67.5	33.5	79.3	29.3
College, University, Schools	0.7	1.7	2.3	2.1	2.7	2.4
TOTALS MGD	125.0	435.3	590.1	423.9	693.4	423.0
Ac. Ft./Yr.	140,000	487,000	660,000	473,000	774,000	473,000
PERCENT REDUCTION			28%		39%	

*These figures assume that no major power generating stations will be constructed in the Las Vegas Metropolitan subarea.
**Boyle-CH_2M report, Table 14.3 (8).

State Engineer, January, 1971

Table 23 - Concentration of Water

State Engineer, January, 1971

Literature Cited

1. State Engineer, "Nevada's Water Resources", State of Nevada Water Planning Report, October, 1971, 87 pp.
2. State Engineer, "Water Supply for the Future in Southern Nevada", Special Planning Report, January, 1971, 89 pp.
3. State Engineer, "Estimated Water Use in Nevada", State of Nevada Water Planning Report, January, 1971, 32 pp.
4. NECON, "Water Quality Management Plan for Clark County, Nevada", March, 1973.
5. Malmberg, Glenn, "A Summary of the Hydrology of the Las Vegas Ground-Water Basin, Nevada, with Special Reference to the Available Supply", Water Resources Bulletin No. 18, 1961, 23 pp.
6. Maxey, G.B. and Jameson, C.H., "Geology and Water Resources of Las Vegas, Pahrump, and Indian Spring Valleys, Clark and Nye Counties, Nevada", Water Resources Bulletin No. 5, 1948, 43 pp.
7. Glancy, Patrick, "Water Resources Reconnaisance Series Report 46 (Mesquite-Ivanpah Valley)".
8. Walker, George and Eakin, Thomas, "Ground-Water Resources - Reconnaissance Series Report 14 (Amargosa Desert)", March, 1963, 45 pp.
9. Davis, Stanley and DeWiest, Roger, "Hydrogology", Wiley and Sons, Inc., NY 1966, 454 pp.
10. Udall, Stewart; Dominy, Floyd and West, A.B., "Support on Southern Nevada Water Supply Project", Project Development Report, August, 1963, 95 pp.
11. Maxey, G.B. and Robinson, T.W., "Ground Water in Las Vegas, Pahrump and Indian Spring Valleys, Nevada", Water Resources Bulletin No. 6, 1947, 23 pp.
12. Rush, Eugene, "Water Resources - Reconnaissance Series Report 50 (Lower Moapa - Lake Mead)", December, 1968, 66 pp.
13. State Engineer, "Forecasts for the Future Population", State of Nevada Water Planning Report, Feb., 1973, 76 pp.
14. U.S. Dept. of Health, Education and Welfare, "Public Health Service Drinking Water Standards", Public Health Service Publication No. 956, 1962.

Literature Cited

1. State Engineer, "Nevada's Water Resources", State of Nevada Water Planning Report, October, 1971, 87 pp.
2. State Engineer, "Water Supply for the Future in Southern Nevada", Special Planning Report, January, 1971, 89 pp.
3. State Engineer, "Estimated Water Use in Nevada", State of Nevada Water Planning Report, January, 1971, 32 pp.
4. NCCOW, "Water Quality Management Plan for Clark County, Nevada", March, 1973.
5. Malmberg, Glenn, "A Summary of the Hydrology of the Las Vegas Ground-Water Basin, Nevada, with Special Reference to the Available Supply", Water Resources Bulletin No. 18, 1961, 23 pp.
6. Maxey, G.B. and Jameson, C.H., "Geology and Water Resources of Las Vegas, Pahrump, and Indian Spring Valleys, Clark and Nye Counties, Nevada", Water Resources Bulletin No. 5, 1948, 43 pp.
7. Clancy, Patrick, "Water Resources Reconnaissance Series Report #46 (Mesquite-Ivanpah Valley)".
8. Walker, George and Eakin, Thomas, "Ground-Water Resources - Reconnaissance Series Report 14 (Amargosa Desert)", March, 1963, 45 pp.
9. Davis, Stanley and DeWiest, Roger, "Hydrogeology", Wiley and Sons, Inc., NY 1966, 454 pp.
10. Udall, Stewart; Dominy, Floyd and West, A.B., "Support on Southern Nevada Water Supply Project", Project Development Report, August, 1963, 95 pp.
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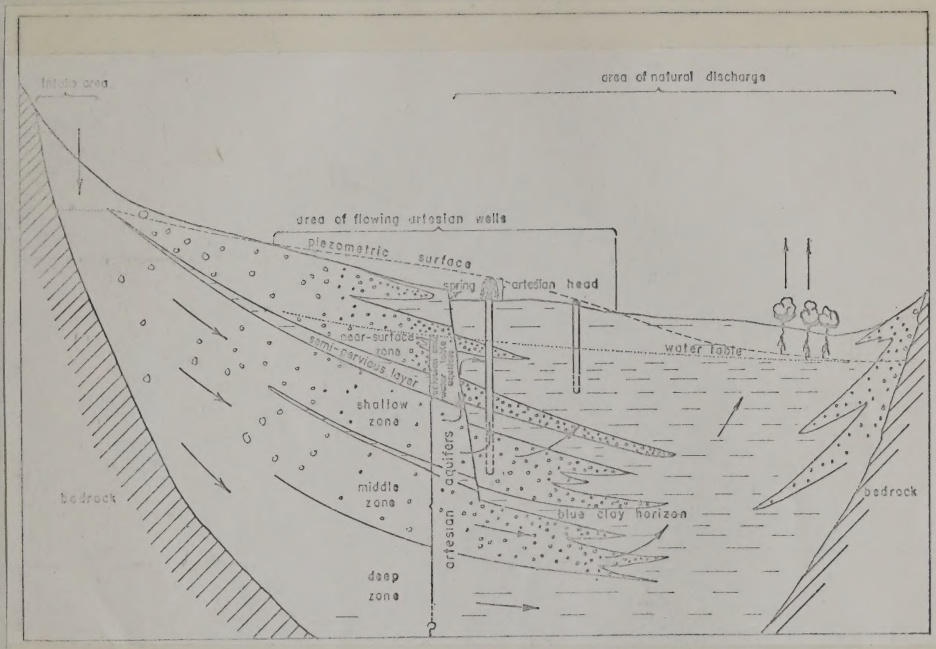

Diagrammatic east-west section across Las Vegas Valley showing the principal zones of aquifers, direction of ground-water movement, and general geology of the valley fill.

Figure 1 - Ground Water Movement through Principal Zones of Aquifers

Malmberg, 1961

Figure 1 - Ground Water Movement through Principal Zones of Aquifers

Meinzer, 1961

STATELINE PLANNING UNIT

Vegetation Step 2

See Overlay #2.

We have used more detail than required since the area is almost all desert shrub and little purpose would be served by a mono-chrome overlay.

Ecotones caused by elevational changes are quite sharp. At lowest levels are the bare playas.

As the elevation rises, we find:

1. Salt desert shrub, usually shadscale (Atriplex confertifolia)
2. Creosote bush (Larrea divericata)
3. Creosote bush over burro-sage (Ambrosia dumosa)
4. Spanish dagger (Yucca schidigeri)
5. Joshua tree/over burro-brush
6. Joshua tree over blackbrush (Coleogyne ramosissima)
7. Blackbrush
8. Joshua tree over sagebrush (Artemesia tridentata var.)
9. Pinyon (Pinus monophylla) juniper (Juniperus osteosperma) over sagebrush

Due to past fires and cutting, there are no known ponderosa pine (Pinus ponderosa) left in the area except on the NW side of Charleston Mtn. near the U.S.F.S. boundary.

As one might suspect from reading the section on Climate, almost all of the Stateline Unit is true desert. Grasses are normally non-existant, and usually make a very minor percentage of the vegetative stand at best. Because of the wide fluctuations in annual precipitation, production of forage by perennial plants will vary over 1000% between wet and dry years. This can have an extreme effect on livestock and wildlife populations. During the rare wet year, flowers carpet the desert and residents and tourists flock to the desert to view the spectacular displays. Production of annual plants can vary from less than 1 lb./acre to over 3 tons/acre, depending upon amounts and timing of precipitation.

Poisonous or noxious weeds are uncommon. No reports of losses of livestock have been received. In a few disturbed areas barbedwire russian thistle will dominate and deny access to livestock and man due to its sharp spines.

Range types will be discussed briefly here. See Range Management section for a complete write-up.

1. Grassland

   These are small islands of grass, usually tobosa (Hilaria rigida or H. jamesii). The grasses are important to livestock and wildlife (especially bighorn sheep) and wild horses and burros. These islands

of galleta grass are usually less than 100 sq. ft. The islands of tobosa may cover several acres. Reproduction is by rootstalks, not by seed, so propagation of new plants is very slow, about 1 linear foot/20 years. The grasses are destroyed by vehicles, requiring new growth from the rhizomes. They are quite resistant to grazing.

5. Broadlead Browse Plants

These are small (10-500 acres) areas which have been burned in the past. They are important to all grazing animals for forage and cover. Access is difficult because of the stiff sharp stems on manzanita (Arctostaphyllus pungens) and others.

7. Rocky Areas

These areas are nearly devoid of forage plants or are so steep and rough as to be inaccessible to livestock. They are used by bighorn sheep for escape cover. In a few post-climax sites within a 7 type there may be grasses relished by the bighorn.

8. Barren

Playas (dry lakes) and bare rock areas.

9. Pinyon-Juniper

This is a varied type as far as understory is concerned. It is on steep to precipitous slopes for the most part. The type can produce limited Christmas trees and posts. It is suspected that growth is very slow in this Planning Unit. The type produces very limited forage because of the tree competition. It can be used as escape cover by wildlife, wild horses, burros and livestock. It is excellent scenery in the dry hot months in the desert.

11. Creosote Bush (Larrea tridentata)

This very large type has a very low density of plants (usually 2 to 4%). The soil is usually protected by erosion pavement from the elements. Reproduction of plants is a rare event. The type is low in forage production for livestock and wildlife except in very wet years when ephemeral plants abound.

13. Saltbushes

The type is found at the lower elevation levels near Quaternary lake boundaries. Due to salinity, reproduction is difficult. The plants are brittle and break easily under vehicular traffic. The type is minimal in forage production, but can produce limited winter and spring forage.

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12. Mesquite Type

This is a small type occupying sand dunes on the edges of the Pleistocene lakes. It may produce some forage for wildlife and livestock.

16. This is a large and varied type of many of the desert shrubs

Included are Spanish dagger (Yucca schidigera), Joshua tree (Yucca brevifolius) and blackbrush (Coleogyne ramosissima). Protection to soil is provided primarily by erosion pavement. Reproduction of the overstory plants appears to be mostly by underground root stalks, with seed playing a minor part in the establishment of new plants. Most of the forage of the unit is produced in this type. Topography is fairly gentle and is favored by outdoor enthusiasts, particularly ORV. The Joshua trees are quite scenic and when in flower, the Spanish dagger is very pretty.

State Line (1)

T&R	Gross Acres	Spring Mtn Type I clark BLM Ac	Spring Mtn Type I clark Pvt Ac	Spring Mtn Type II Ac BLM Ac	Spring Mtn Type II Ac Pvt Ac	Amargosa BLM Ac	Amargosa Pvt Ac	Pahrump BLM Ac	Pahrump Pvt Ac	Metropolitan BLM Ac	Metropolitan Pvt Ac	Lake Mead BLM Ac	Lake Mead Pvt Ac	Searchlight BLM Ac	Searchlight Pvt Ac	Other Agencies
15S 49E	20536					20534	2									1739 AEC
15S 50	18505					18355	150									3955 AEC
15S 51	19667			19667												3469 AEC
15S 52	17189			17189												5956 AEC
15S 53	2376			2376												20892 AEC
15S 54	8864			8864												1680 AEC MIL
16-48	20124					10856	9268									12178 WL
16-49	23177					16307	6870									
16-50	23039					22777	400									
16-51	23020			22700	320											
16-52	23028			22868	160											
16-53	23034			23034	—											
16-54	21898	13098	—	8800	—											1128 M.L.
16-55	21119	21119	—													1928 M.L.
16-55½	6401	6321	80													575 mil
16-56	19238	19177	61													(4117 Mil)
16-57	8680	8680	—													14356 mil
17 48	2491	—				1269	1172									
17 49	21017					17739	3278									
17 50	22079					15714	6360									
17 51	22670					22246	424									
17 52	22867					21267	320	1200	80							
17 53	22722					20817	625	1200	80							
17 54	22708	10822	—	11976	—											
17 55	22823	22503	320													
17 56	22940	22078	160													
17 57	22413	22413	—													
17 58	18772	18772														4156 mil
17 59	22735	3778	—													
18 49	2414	—				2079	335									
18 50	20861					15658	5203									
18 51	22955			20163	2792											
18 52	22973			19133	—			3760	80							
18 53	22979		—	5118	0			9721	8360							
18 54	23045	9539	—	13496	—											
18 55	22963	17123	80													5760 NF
	689322	195483	701	195334	3,272	205618	34907	31	8600							

State Line (2)

T & R	Gross Acres	Spring Mtn Type I, Clark BLM Ac	Spring Mtn Type I, Clark Pvt Ac	Spring Mtn Type I Nye BLM Ac	Spring Mtn Type I Nye Pvt Ac	Amargosa IV BLM Ac	Amargosa IV Pvt Ac	Pahrump IV BLM Ac	Pahrump IV Pvt Ac	Metropolitan IV BLM Ac	Metropolitan IV Pvt Ac	Lake Mead VII BLM Ac	Lake Mead VII Pvt Ac	Searchlight BLM Ac	Searchlight Pvt Ac	Other ownership
18S 56E	22755	11870	231													10,854 NF (800 Pvt)
18 57	22995	21735	—													1260 NF
18 58	22966	22966														
18 59	22912	11924	160							10829	—					
18 60	8614	8614	—													14,383 W
19 58	1658	1658	—													
19 59	19131	14131	—													
26M 7E	6192	6192	—													
25M 7E																
19 52	23013	15329	—					5284	2400							
19 53	23007	—	—					1775	21232							
19 54	23074	9554	40	13480	—											
19 55	23002	18519	—													4488 NF (200 Pvt)
19 56	22282	—	—	—				—	—							22,282 NF
19 57	23024	17914	160													7950 NF
19 58	22996	22996	—													
19 59	22958	9569	—							9039	4355					
19 60	23038	—	—							5059	17979					
19 61	22993									13012	9981					
19 62	19612									8146	6766					8361 Mil.
19 63	9365									9635	—					3391 Mil. Acq'd in VV Area
T 20S 51E	52	—	—	—	—	—	—	52	—							
20-52	12923			1849	203			3143	7728							
SBM 24N 7E																
SBM 25N 8E				605												
" 24N 8E	6381	—	—			—	—	6381	Not record							
" 23N 8E																
20 53	23028	—	—	—	—	—	—	—	23028							
20 54	23045	9600	—	9288	—	—	—	2180	1977							
20 55	23049	23049	—													
20 56	23025	17740	160													
20 57	22978	17978	560													5125 NF
	510538	258333	1311	25222	203			18815	56365	55720	38781					4490 NF

Stateline (3)

T&R	Gross Acres	Spring Mtn Type I Clark BLM Ac	Spring Mtn Type I Clark Pvt Ac	Spring Mtn Type I Nye BLM Ac	Spring Mtn Type I Nye Pvt Ac	Amargosa IV BLM Ac	Amargosa IV Pvt Ac	Pahrump IV BLM Ac	Pahrump IV Pvt Ac	Metropolitan III BLM Ac	Metropolitan III Pvt Ac	Lake Mead III Govt Ac	Lake Mead III Pvt	Searchlight I BLM Ac	Searchlight I Pvt Ac	Other Agencies
20s 58	23049	22729	320													
20 59	23007	8295	—							585	14124					
20 60	23050	—	—	—	—	—	—	—	—	4787	18263					
20 61	23023									—	23023					
20 62	23026									2720	18386					320 Mil 1920 VV Acre
21 52	169							169	—							
21 53	17136							11827	5309 (10,600 Nye)							
21 54	22949	7916						150 Nye 8785	8535 Clark 12248 (1,440 Clark)							
21 55	22943	18818	960					3165	—							
21 56	22944	23944	—													
21 57	22921	23921	—													
21 58	22892	22771	121													
21 59	23007	3283	3734							12923	3067					
21 60	23006									4647	18359					
21 61	22893									554	22289					5 Mil
21 62	22857									4942	16835					1030 R Asst VVA Acre
21 63	17481									8122	3359					
21 63½	929											929				
21 64	5267											5267				
22 53	899							5703 Nye 8480 Clark				899				
22 54	14609							1928	2321 (1537 Nye 784 Clark)							
22 55	22967	636	—					21053	—					1278	—	
22 56	22961							3825	—					19136		
22 57	22992													22912	80	
22 58	23219													21296	1918	
22 59	23000									14711	1892			6397	—	
22 60	22949									12136	9539			1199	70	
22 61	22039									7002	15037					
22 62	23020									3939	17661			1920	—	
22 63	23098									12521	10577					
22 63½	2232									2232	—					
22 64	23033									3675		19358				
22 65	5924											5924				
23 54	389							235	154							
23 55	15275							19111	164							
23 56	23026							7668						15358		
	650108	126313	5135					86116	20196	94696	192411	36026	80	89496	2068	

T & R	Gross Ac	Spring Mtn Type I Clark	Spring Mtn Type II Nye	Amargosa IV	Pahrump IV BLM Ac	Pahrump IV Pvt Ac	Metropolitan IV BLM Ac	Metropolitan IV Pvt Ac	Lake Mead III Govt Ac	Lake Mead III Nthr	Searchlight I BLM Ac	Searchlight I Pvt Ac	other Agencies
23 57	23019										22639	380	
23 58	22982										22661	321	
23 59	23007										22007	—	
23 60	22945						3683	140			18672	450	
23 61	22976						8264	4475			10237	—	
23 62	23025										23025	—	
23 63	23025						13396	3879			5750	—	
23 63½	23017						1062	1275					
23 64	23025						20715	10	2308	—			
23½ 69	27917						2272	—	475	—			
23½ 65	21988								2198	—			
23 65	9428								9490	—			
24 55	199				199	—							
24 56	13521				1961	3005					2495	60	
24 57	23039				4353	680					18697	553	
24 58	23047										21858	1189	
24 59	23028										22868	160	
24 60	23017										22657	360	
24 61	23036										23036	—	
24 62	23035										23035	—	
24 63	23215						23215	—					
24 64	23136						7727		3849		11565	—	
24 65	17974								17974				
25 56	131												
25 57	13110				835	3877					6818	80	
25 58	23029										22470	559	
25 59	23018										22183	835	
25 60	22988										22988	—	
25 61	22883										22883	—	
25 62	22868										22868	—	
25 63	22225										22225		
25 64	23136										23061	75	
25 65	16897								16897				
26 57	97										97	—	
26 58	14051										13996	55	
26 59	23023										26698	325	
	644287				6654	7562	90334	9849	53136		477389	5402	

Stateline (6)

T & R	Gross Ac	Searchlight I BLM Ac	Searchlight I Pvt Ac	Lake Mead II Govt Ac	Lake Mead II Pvt Ac	Other
30 65	22599	11139	130	11330	—	
30 66	14428			14428	—	
31 63	9093	9093				
31 64	23003	22843	160			
31 65	23022	11464	—	11558	—	
31 66	19218			19158	60	
32 64	8859	8694	165			
32 65	23028	22388	—	640	—	
32 66	20635	11113	5268	9254		
33 65	4702	4702	—	—	—	
33 66	7079	6251	828	—	—	3350 IR
34 66	78	78	—			322 IR
	175694	107715	6551	61368	60	3672 IR

T & R	Gross Ac	Searchlight I BLM Ac	Searchlight I Pvt Ac	Lake Mead II Govt Ac	Lake Mead II Pvt Ac
26 60	22988	22988	—		
2661	22992	22902	90		
2662	24348	24348	—		
2663	23086	23086	—		
2664	22959	21904	1055		
2665	18680	—	—	17920	760
2758	102	102	—		
2759	17495	16900	595		
2760	23018	23018	—		
2761	23015	23015	—		
2762	22993	22993	—		
2763	23145	23145	—		
2764	22902	22802	100		
2765	22865			22745	120
2762½	165	165	—	859	
766	859				
2859	52	52	—		
2860	14129	14039	90		
2861	23033	22508	525		
2862	23898	22618	1280		
2863	21465	19852	1613		
2864	23026	22621	405		
2865	21988			21988	
2866	140			140	
2961	10396	10351	45		
2962	22878	22878	—		
2963	22863	22223	640		
2964	22935	22920	15		
2965	22948	22948	—		
2966	6644			5111	1531
3062	9812	9787	25		
3063	22961	22961	—		
64	22952	22166	787		
	583681	505292	7215	68763	2911

Soils - Stateline Planning Unit

General

The soil is surface material, naturally produced, in which plants may grow. It is the product of the disintergration of rocks, organic material, water and air in varying proportions. The rock material is fragmented through spalling mainly and then altered by the chemical processes of weathering.

Soils have distinctive layers, or horizons, that are the result of the interaction of climate, topography and vegetation with the parent rock material (see profile on following two pages). The length of time that these forces have acted on the parent material determines the type and degree of maturity of the soil produced.

Under the arid desert conditions that prevail in all but the highest elevations within this unit, there is but little leaching away of the soluble constituents of soils and this is confined mainly to the translocation of the soluble material (usually lime) from the surface to the subsoil with the resultant formation of a hardpan (petrocalcic horizon).

The most intimate relationship exists between the occurrence and distribution of soils and the geology, physiography, climate and vegetation of an area.

Geology and Land Forms

Throughout the basin and range province there is a sharp contrast in physiography between mountainous areas and interior lowlands. This contrast produces a wide variation in environment for soil development through gross differences in slope gradient, exposure and climate. Continual creep of soil materials often disrupts or destroys soil horizons during or after their development. Contrast in exposure is often sufficient to establish different vegetative types which can in turn cause wide variation in soil characteristics.

The landscapes of southernmost Nevada are dominated by long, gently sloping alluvial fan piedmonts which merge upwards onto relatively broad bedrock pediments. Pediment reentrants extend deeply into the low, rugged mountains; in many places, they join from opposite sides of a range to form pediment passes. The mountain slopes are rough and angular with extnesive rock outcrops. Throughout this area, and particularly on drainages to the Colorado River, loamy-skeletal and lithic Entisols[1] are the most extensive soils between the rock outcrops of the mountain slopes. Extensive areas of loamy-skeletal Entisols on the alluvial fan

1 For definations of terms see appended publication "Soil Series of the United States, Their Taxonomic Classification" SCS.

piedmonts below the barren mountains must be synchronous with the erosion cycles which stripped so much soil mantle from the mountains; Argids and Orthids on stable fan and mountain slope remnants are evidence of these former soil mantles. In physiography, in evidence of widespread, relatively recent erosion, and in warm soil temperatures and vegetation, southernmost Nevada is more similar to the eastern Mojave desert, California, than to the rest of Nevada.

Limestone bedrock is common in southern and eastern Nevada, whereas volcanic bedrock is dominant throughout the remainder of the state. Calciorthids and Paleorthids are most common on the limestone mountains and alluvial fans derived from them. On terrain underlain by volcanic rocks or sediments, Haplargids or Durargids are most common. In southernmost Nevada, the most extensive areas of Argids (shown at the northwest corner of the general soil map, map units 71 and 72) reflect the southern extension of west-central Nevada's volcanic bedrock terrain. Mountain ridges and crests are broadly rounded and mantled with soil; only the highest, most precipitous mountains show extensive rock outcrop.

Throughout Nevada, a peculiar landform occurs which reflects the antiquity of landform modeling. This is the ballena, or "whale-back". Ballenas are elongated, straight-topped ridges which are so completely rounded, transversely, that the shoulders from both sides meet in a smooth curve across the crest. Commonly, several ballenas will occur parallel to each other, and will have accordant, straight ridgelines since they are the remnants of dissected alluvial fans or pediments. They are most common at the base of a mountain range where they stand above smooth alluvial fans, or above dissected fan remnants with yet preserved, flattish tops. A flat-topped fan remnant commonly has an older, different soil on top, where the old fan surface is preserved, than on the younger remnant sideslopes. With ballenas, shoulder rounding has destroyed the old fan surface, and a very similar soil extends from the sideslopes over the crest. At the base of the Spring Mountains many ballenas with petrocalcic horizons extending over and down their sideslopes can be seen.

Genesis of Soils

In this region where rainfall is low and highly variable and where daily temperature range is 30 to 50 degrees F. (annual range can be 120 degrees F.), rocks of all kinds tend to break down more by disintegration rather than decomposition. Spalling type mechanical breakdown exceeds chemical action. As a result, even the highest mountains are covered with a thin veneer of rock fragments. Cloud bursts and showers sweep large volumes of this material into ravines and valleys forming alluvial fans of the coarser material on the slopes. Some of these fans are as much as four miles in radius. The fine material is washed quickly into the lowlands. However, there are extensive, stable land surfaces on the mountains as well as the basins. Many of these stable surfaces are relicts of the Pleistocene. Argids are the most common soils on the ancient surfaces.

The small moisture supply limits vegetative production to desertic shrubs, cacti, and rarer forbs and grasses and annuals. The last are more prevalent in locations where moisture stress is higher. The vegetation is normally sparse, and the exposed ground surface ranges usually between 50 and 95 per cent. The effectiveness of the vegetation is further reduced by insect activity and the blowing away of the dry leaves and stems of the grasses and shrubs. The amount of organic matter in the sola is usually less than 1 per cent.

A gravelly surface mantle is characteristic and is commonly referred to as a desert pavement. Such a surface is stable and resistant to erosion. Erosion is normally active on surfaces lacking this pavement. The sparse cover of vegetation does little to reduce wind and water velocities. When grazed, trampling pulverizes the exposed surface between plants, and erosion is accelerated. Erosion is a major factor in recharging surface soils with carbonates through the movement and deposition of calcareous dusts.

The age of the soils is usually related to landforms. Age is evidenced in places by strong Bt horizons or thick formations of caliche or cemented pans. These are commonly carbonate pans but in places contain significant quantities of siliceous cements. Parent materials exert an especially strong influence on the characteristics and qualities of desertic soils. They seem to determine to a marked degree the sequence and intensity of development. If the parent materials are relatively low in alkaline carbonates and soluble salts and the salts and carbonates are leached, weak to moderate carbonate horizons form at a depth of 15 to 30 inches, and the soluble salts, even though low in total amount, increase somewhat with depth below the maximum accumulation of carbonate. A thin, light-colored A horizon and a distinct moderately strong textural B horizon form. The ratio of the clay in the Bt horizon to that in the A horizon ranges from 1.2 to 2.0 in the zonal desertic soils.

In places the carbonate content may be sufficient to cause a cementation in the carbonate horizon, particularly if gravel and cobble make up a large part of the horizon. Where volcanic ash or glass provide a rich source of relatively soluble silica, the cementation is more pronounced.

In the most common situation the parent materials are moderate or high in alkaline earth carbonates and contain significant quantities of soluble salts. There is some translocation of salt and carbonate, causing an increase at depths of 15 to 30 inches. The highest concentrations of salt are in or below the horizons of maximum carbonate accumulation. However, the soil remains moderately to strongly calcareous throughout. A distinct textural B horizon forms with a clay increase ratio up to 1.5 to 2. The Bt is usually sodium affected at least in the lower part, indicating the influence of sodium in peptizing and increasing the mobility of clay.

The thickness of the fine sediments in some of the large valleys and depressions can only be conjectured, but is often over 2,000 feet and in places as much as 20,000 ft. thick! In areas where there is no external drainage, dissolved salts accumulate at or near the surface of these sediments forming the many playa "lakes" common to the region.

Wind is also an active agent in soil genesis in this region. Wind blown sand is found from the valleys to the tops of the hills and mountains. The greatest accumulations are found in the lower valleys often forming dune areas. Fine wind blown silts mixed with fine alluvium washed from the slopes forms the soil mantle of the valleys. Bushes and plants often accumulate a wind blown silt cone (termed coppice dunes) that forms around the base of each plant where wind velocity is decreased enough for it to drop its load. The term "blow sand" arises from the fact that much of the surface soils are wind deposited. During the spring there are often severe wind storms that last for several days during which there is so much airborne dust that visibility is seriously limited. Obviously during such wind storms, enormous quantities of soil materials are transported.

Organic matter in most desertic soils is far less than the average 3-5% by weight contained in a normal top soil. Even in a wet year when there is a large growth of spring annuals, much of the vegetable material is oxidized by the later summer heat before it can be covered and turned to humus. Soil temperatures up to 150°F. are common in the desert during the hot months. At temperatures above 130°F. most plant and animal microorganisms necessary for plant growth are killed. This accounts for the completely sterile nature of some of the hottest desert soils and the limited, specialized plants in slightly cooler soils.

In desertic regions the small quantities of moisture received (about 4 inches per year) limits leaching and restricts the production of vegetation. Under such conditions the soils are thin. The soluble salts are usually leached only to depths of 1 to 2 feet.

The high temperatures of this area increase evaporation rates and reduce the amount of water available for transpiration by plants. High temperatures accelerate weathering, and desert crusts are common on gravel and stone exposed on soil surfaces. The mafic and feldspathic materials are well oxidized, and red hues are common in the soils.

Generally, the quantity of moisture is insufficient to eluviate clay; and Bt horizons when present are due largely to clay formation in place.

When the parent materials are high in alkaline carbonates and low in soluble salts, there is translocation of carbonates as above; but only weak (structural) or no B horizons form.

The A horizons are thin, generally less than 4 to 6 inches, are light colored, usually platy, and with pronounced vesicular porosity in the topmost layers. Commonly, the A horizons are bleached and lower in organic matter than the immediately underlying B horizon.

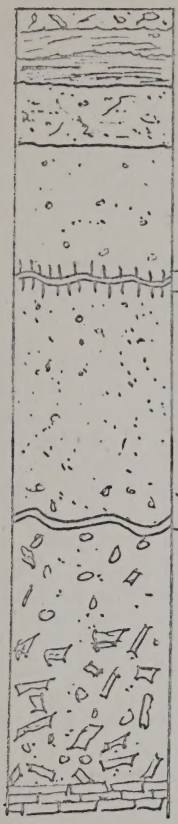
The B horizons are thin, brighter, weakly to moderately developed, and have a characteristic very fine blocky structure in the upper part becoming coarser in the main portion.

Horizons of carbonate accumulation occur in the lower or C horizon and commonly within 20 inches of the surface.

In the areas of the Red Desert soils the A horizon is thin, has a red hue, and the organic-matter content is generally less than 0.6 per cent. The B horizon typically contains more clay and is as red or redder than the A and is mildly to strongly alkaline. A horizon of carbonate accumulation which may be cemented occurs in or below the B horizon. Surface gravels in old desert pavement areas have a dark-colored desert varnish.

The Desert soils are similar except that the hues of the A and B horizons tend to be brown or yellowish brown. Desert crusts are less pronounced.

A THEORETICAL SOIL PROFILE SHOWING ALL
OF THE HORIZONS THAT CAN BE DEVELOPED



O_1 Litter

O_2 Raw Humus

A_1 Humus Incorporated Layer

A_2 Leached (eluvial) Zone

A_3, B_1 Transitional Zones

B_2 Enriched (illuvial) Zone

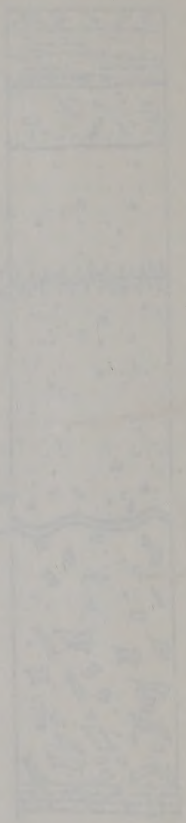
B_3 Transitional

C Parent Material

O_1 Loose organic debris. Usually deep in forest lands. Thin or almost absent in some lands.

O_2 Organic matter may be matted, fibrous or granular on forest land two layers may be developed - F the fermentation zone and H - a humified zone.

A_1 A dark horizon with the major amount of humified organic matter well mixed with mineral material. In a mature forest soil this horizon may be thin or missing while in grasslands it may be very thick.



A_2 A light colored horizon resulting from leaching and bleaching action. Usually absent from arid and semiarid soils.

A_3 Transition Zone - often absent. More like A than B.

B_1 Transition Zone - often absent. More like B than A.

B_2 A zone of accumulation - especially of clays and iron and aluminum compounds. Hardpans occur here. In arid zones B_2 is often characterized by special forms, i.e. columnar or prismatic.

B_3 Transitional Zone - sometimes absent.

C Regolith - unconsolidated parent material. This may be from bedrock below, or transported from elsewhere and deposited on the bedrock.

Classification of Soils in the Stateline Planning Unit

Soils in this planning unit vary from almost completely sterile desertic soils to the forest soils of the higher elevations. Valleys are deeply cut into old alluvial fans and lake-laid sediments which form bench lands on both sides. The valley lands consist of comparatively level bottom lands and gently sloping fans at the mouths of the lateral washes which flow down from the higher bench lands. The edges of these bench lands form distinct escarpments several hundred feet high in places. They are thoroughly dissected by erosion.

On account of the deep cutting by the streams, the higher benches have very well (excessively) drained soils. Some of the bottom lands, however, are so poorly drained as to be considered swampy.

The included general soil map and legend for southernmost Nevada shows Aridisols and Entisols are the co-dominant soils. The Entisols have only indistinct or no genetic horizons and occur on young land surfaces both on the alluvial plains and on the mountains. They have torric soil moisture regimes (i.e., equivalent to aridic), and are effectively dry throughout the soil moisture control section (i.e., 8-24 inches for the most common, coarse-loamy textures) more than half the time they are warmer than 5°C at 50 cm. (Except in the high mountains, few soils get as cold as 5°C at 50 cm. even in January-February.) There is no period as long as 90 consecutive days when they are moist in some part of the moisture control section. The Entisols are mostly Torriorthents with loamy-skeletal or coarse-loamy textured control sections; some Torripsamments and Torrifluvents are moderately extensive.

The Aridisols have distinct genetic horizons and aridic soil moisture regimes. In the higher mountains, some have moisture regimes marginal to ustic, and are identified in ustollic subgroups. Among the Aridisols, the Orthids are more common than the Argids--reflecting predominance of limestone-rich parent material. The Orthids most commonly have calcic horizons as the most prominent genetic horizon (Calciorthids), though many have petrocalcic horizons (Paleorthids). Loamy-skeletal or coarse-loamy control sections are most common among the Orthids.

The Argids necessarily have argillic horizons; some in lowland positions have natric horizons; some have additional duripans or petrocalcic horizons. Fine-loamy and loamy-skeletal control sections are most common. The Argids are geographically associated with parent materials rich in volcanic rocks and poor in limestone content.

The Aridisols are all on at least moderately old, stable land surfaces. Those soils with merely calcic or argillic horizons are on the later Pleistocene surfaces; those with duripans or petrocalcic horizons are on late to mid-Pleistocene surfaces and generally are topographically higher in the landscape. Soils on ballenas frequently have pan horizons, or at least calcic or argillic horizons.

A few Salorthids (with salic horizons) occur in lowland positions where water tables are high. Gypsiorthids (with gypsic, rather than calcic horizons) occur in materials rich in gypsum and limestone; a few gypsum cemented pans, or petrogypsic horizons. There is one extensive area of Vertisols, or Torrerts, on fine sediments in Pahrump Valley, northwest of Las Vegas.

A few Mollisols occur in the high Spring Mountains and the Sheep Range under open coniferous forests and sagebrush "balds". These are Ustolls (Lithic Haplustolls), since summer thunderstorms are frequent enough to create a ustic soil moisture regime. Except for southernmost, and southereastern Nevada, the Mollisols of the mountains and high plateaus are Xerolls. The ustic soils receive significant moisture during the growing season, whereas Xeric soils are moistened primarily in the winter, and plants grow in spring and early summer on largely stored soil moisture.

The soils of this area are warm. Most have thermic soil temperature regimes (15-22°C, or 59-72°F mean annual soil temperature at 50 cm., greater than 5°C, or 9°F difference in mean summer and winter temperatures at 50 cm.). A year's monthly soil temperature measurements shows that a narrow band of soils, right along the Colorado River at roughly 1000 feet elevation, are barely into the hyper thermic class (measured 24°C MAST) occur between roughly 6,000 and 9,000 feet elevation; soils with frigid soil temperature regimes might occur about 9,000 feet elevation.

* MUST REFER TO SOILS WITH MESIC TEMPERATURE REGIMES

Relation of Soils to Wildlife Habitat

The wildlife population of any area depends on the availability of food, cover and water in suitable proportions. Habitats can be created, maintained or improved by establishing desirable vegetation and developing water supplies in areas where suitable soils are available.

Soils directly influence the kinds and amounts of vegetation that can be produced and thus influence the kinds of wildlife that can exist in any area. The factors that affect soils and their productivity of wildlife feeds are: (1) thickness of the soil useful for plants, (2) surface texture, (3) available water capacity to a depth of about 40 inches, (4) wetness, (5) flood hazard, (6) slopes, and (7) soil permeability to air and water. A careful evaluation of soil characteristics should be included in any study of wildlife habitat improvements.

The Spring Mountains and McCullough Mountains have areas with sufficient soil dpeth (and precipitation) to have a reasonable chance of success of a wildlife vegetation planting.

Engineering Uses of Soils

Any form of construction on the earth surface requires a good understanding of the engineering properties of the soils upon, or through, which the project will take place. All too often plans are drawn up and work started, or even completed, only to find that inadequate provisions had been made for a soil condition which later becomes evident in the form of a failure of the project. A heavy rain or earthquake causes a landslide, or a building foundation cracks and settles, or any number of other destructive forces can extract their toll for incomplete soils evaluation.

Among the properties of soils important in engineering are: permeability and porosity, compressive strength, compaction characteristics, ability to hold water, shrink-swell potential, screen analysis, plasticity and chemical activity (pH etc.). Depth to water table and bed rock must be considered.

These properties combine to influence to varying degrees the construction of roads, bridges, pipelines, dams, irrigation systems, canals, reservoirs, settling, and sewage ponds, buildings, etc.

Prior to the initiation of any construction project an evaluation of potential damaging forces should be made. Tests should then be conducted of soil and related geological characteristics that could allow these forces to come into play and steps taken to counter delitirous conditions.

The Muddy Creek Formation is patently unsuitable for most construction purposes due to swell-shrink properties of hygroscopic salts.

BIBLIOGRAPHY

Buckman, H.O. & Brady, N.C. The Nature and Properties of Soils, 1960

Cooley R.L. et al. Influence of Surface and Near-Surface Caliche Distribution on Infiltration Characteristics and Flooding, Las Vegas Area, Nev., February 1973, Desert Research Institute

Downs, J., Naphan, E., Peterson, F., General Interest Soils Tour Brochure, November 1973, Overlay map from this source.

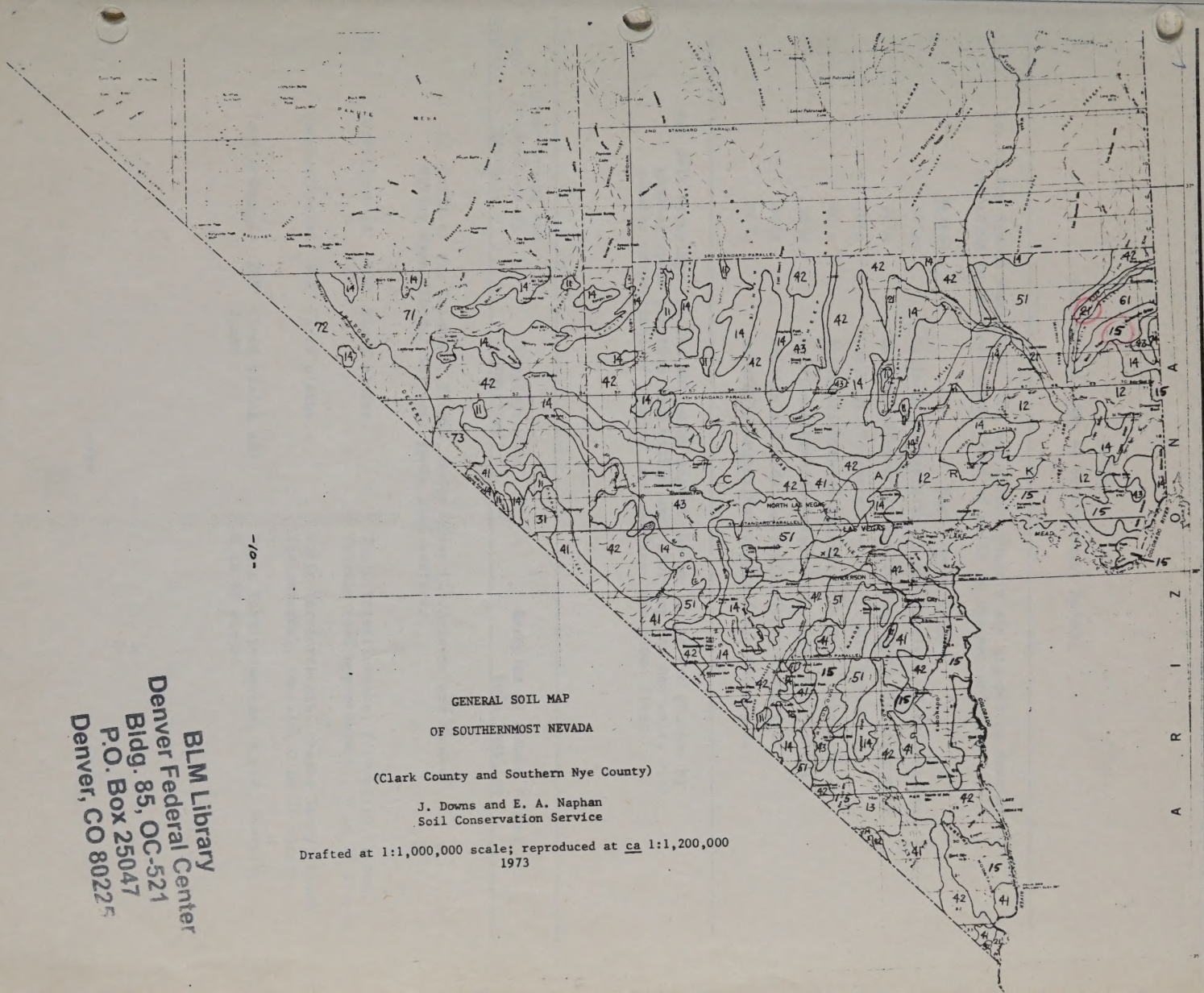
Trask, P.D., Applied Sedimentation, John Wiley & Sons, 1950

U.S.D.A. (SCS), Soil Survey, Las Vegas and Eldorado Valleys, Nevada Series 1957, No. 23; 1967.

U.S.D.A. (SCS), Meadow Valley Soil Survey Area, Nevada - Utah, unpublished manuscript, March 1973.

U.S.D.A. Joint Pub., Soils of the Western United States, Sept. 1964

Youngs, F.O., Soil Survey of the Moapa Valley Area, Nev., U.S. Dept. of Agriculture, Bureau Chem. & Soils, 1928



GENERAL SOIL MAP

OF SOUTHERNMOST NEVADA

(Clark County and Southern Nye County)

J. Downs and E. A. Naphan
Soil Conservation Service

Drafted at 1:1,000,000 scale; reproduced at ca 1:1,200,000
1973

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21 & 70
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LEGEND

General Soil Map of Southernmost Nevada

Key to Map Symbol Numbering: The map symbol numbers are grouped in decades according to the most common kind of soils in the map units:

Decade	Most Common Soils
10's	Entisols:Orthents:Torriorthents:Typic Torriorthents
20's	Entisols:Fluvents:Torrifluvents:Typic Torrifluvents
30's	Vertisols:Torrerts:----------:Typic Torrerts
40's	Aridisols:Orthids:Calciorthids:Typic Calciorthids
50's	Aridisols:Orthids:Paleorthids:Typic Paleorthids
60's	Aridisols:Argids:Haplargids:Typic Haplargids
70's	Aridisols:Argids:Natrargids:Typic Natrargids

Map Unit Grouping: In the following legend the map units are grouped by physiographic position, and within each grouping the map units with greater proportions of younger land surfaces are given first.

Map Symbol	Great Groups and Proportions in Map Unit		Physiographic Position	Examples of Common Phases of Soil Families
	A. Soils of the Colorado, Virgin, Muddy River floodplains and Meadow Valley Wash floodplain; very young land surfaces.			
21	Torrifluvents	40%	Flood plains	Typic Torrifluvents, fine-silty, mixed, thermic (and hyperthermic), 0 to 2% slopes.
	Torriorthents	30%	Flood plains	Typic Torriorthents, coarse-loamy, mixed (calcareous), thermic, 0 to 2% slopes.
	Torripsamments	20%	Flood plains and dunes	Typic Torripsamments, mixed, thermic, 0 to 8% slopes.

Map Symbol	Great Groups and Proportions in Map Unit		Physiographic Position	Examples of Common Phases of Soil Families
	B. Soils of playas, basin-fill plains and lower, smooth or dissected alluvial fan piedmonts; land surfaces commonly are young; sediments are commonly limestone-rich.			
11	Torriorthents	95%	Playas	Typic Torriorthents, fine-silty, mixed (calcareous), mesic, 0 to 2% slopes, frequently flooded.
12	Torriorthents	40%	Smooth alluvial fans and basin-fill plains	Typic Torriorthents, loamy-skeletal, mixed (and fine-loamy, gypsic), thermic, 2 to 8% slopes, shallow.
	Gypsiorthids	30%	Dissected basin-fill plains	Cambic Gypsiorthids, coarse-loamy, gypsic, thermic, 2 to 4% slopes.
	Calciorthids	20%	Smooth and dissected	Typic Calciorthids, loamy-skeletal, mixed (and carbonatic), thermic, 2 to 15% slopes.
31	Torrerts	60%	Basin-fill plains	Typic Torrerts, fine, montmorillonitic, thermic, 0 to 2% slopes, saline.
	Torriorthents	30%	Basin-fill plains	Typic Torriorthents, fine-silty, mixed, thermic, 0 to 2% slopes, saline.
	C. Soils of smooth and dissected alluvial fan piedmonts, ballenas, and foothills; land surfaces are young to old; sediments most commonly are limestone-rich.			
41	Calciorthids	40%	Alluvial fan toe slopes	Typic Calciorthids, coarse-loamy, mixed (and carbonatic), thermic, 2 to 8% slopes.
	Torriorthents	30%	Inset alluvial fans	Typic Torriorthents, coarse-loamy, mixed (calcareous), thermic, 0 to 4% slopes.
	Paleorthids	15%	Alluvial fan toe slopes	Typic Paleorthids, loamy, mixed, thermic, shallow, 2 to 8% slopes.
42	Calciorthids	40%	Smooth and dissected alluvial fans	Typic Calciorthids, loamy-skeletal, mixed (and carbonatic), thermic, 4 to 15% slopes.
	Paleorthids	30%	Smooth and dissected alluvial fans and ballenas	Typic Paleorthids, loamy-skeletal, mixed (and loamy, carbonatic, shallow), thermic, 4 to 15% slopes.
	Torriorthents	20%	Foothills and inset alluvial fans	Typic Torriorthents, loamy-skeletal (and sandy-skeletal), mixed (and carbonatic), thermic, 4 to 30% slopes.

Map Symbol	Great Groups and Proportions in Map Unit		Physiographic Position	Examples of Common Phases of Soil Families
51	Paleorthids	60%	Mesas and alluvial fans	Typic Paleorthids, loamy, carbonatic, (and mixed), thermic, shallow, 0 to 8% slopes.
	Calciorthids	30%	Alluvial fans	Typic Calciorthids, loamy-skeletal, carbonatic (and mixed), thermic, 2 to 8% slopes.
	D. Soils of basin-fill plains, smooth and dissected alluvial fan piedmonts, ballenas, and foothills; sediments commonly contain more or less volcanic rocks, some sediments are limestone-rich; land surfaces are young to old.			
73	Natrargids	30%	Alluvial fans and basin-fill plains	Typic Natrargids, fine-loamy (and fine), mixed, thermic, 0 to 4% slopes, saline.
	Torriorthents	20%	Alluvial fans and basin-fill plains	Typic Torriorthents, loamy-skeletal (and fine), mixed, thermic, 0 to 4% slopes, saline.
	Calciorthids	20%	Alluvial fans	Typic Calciorthids, fine-silty (and loamy-skeletal), mixed (and carbonatic), thermic, 2 to 15% slopes.
	Salorthids	15%	Alluvial fans and flood plains	Typic Salorthids, fine-silty (and fine), mixed, thermic, 0 to 4% slopes.
72	Natrargids	40%	Basin-fill plains and alluvial fans	Typic Natrargids, fine-loamy over sandy or sandy-skeletal, mixed, thermic, 0 to 2% slopes.
	Torriorthents	20%	Basin-fill plains and alluvial fans	Typic Torriorthents, coarse-loamy (and sandy-skeletal), mixed (calcareous), thermic, 0 to 8% slopes.
	Durorthids	15%	Basin-fill plains	Typic Durorthids, loamy, mixed, thermic, shallow, 0 to 4% slopes.
	Calciorthids	15%	Alluvial fans	Typic Calciorthids, loamy-skeletal, mixed (and carbonatic), thermic, 2 to 15% slopes.
71	Natrargids	30%	Alluvial fans	Typic Natrargids, fine-loamy, mixed, thermic, 2 to 15% slopes.
	Nadurargids	20%	Alluvial fans and ballenas	Typic Nadurargids, fine-loamy (and fine), mixed (and montmorillonitic), thermic, 4 to 15% slopes.
	Calciorthids	15%	Dissected alluvial fans	Typic Calciorthids, loamy-skeletal, mixed (and carbonatic), thermic, 4 to 15% slopes.
	Torriorthents	15%	Alluvial fans	Typic Torriorthents, sandy-skeletal, mixed (calcareous), thermic, 2 to 15% slopes.

Map Symbol	Great Groups and Proportions in Map Unit		Physiographic Position	Examples of Common Phases of Soil Families
61	Haplargids	30%	Smooth and dissected alluvial fans	Typic Haplargids, loamy-skeletal, mixed, thermic, 4 to 15% slopes.
	Calciorthids	20%	Smooth and dissected alluvial fans	Typic Calciorthids, loamy-skeletal, mixed, thermic, 4 to 15% slopes.
	Torriorthents	20%	Alluvial fans and channels	Typic Torriorthents, sandy-skeletal, mixed, thermic, 4 to 15% slopes.
	Paleorthids	15%	Dissected alluvial fans and ballenas	Typic Paleorthids, loamy-skeletal, carbonatic (and mixed), thermic, 4 to 15% slopes.
13	Torriorthents	35%	Foothills and upper alluvial fans	Typic Torriorthents, loamy-skeletal, mixed (calcareous), thermic, 8 to 30% slopes.
	Haplargids	25%	Upper alluvial fans	Typic Haplargids, loamy-skeletal, mixed, thermic, 4 to 8% slopes.
	Paleargids	25%	Upper alluvial fans	Petrocalcic Paleargids, loamy-skeletal, mixed, thermic, 4 to 8% slopes.
	E. Soils of mountain slopes and crests, high alluvial fans, and ballenas; limestone and other sedimentary bedrock is most common; some mountain ranges are of volcanic rocks; land surfaces are young to old; soils of map unit 43 are on the highest mountains.			
15	Rock outcrop (Igneous)	40%	Mountain slopes and crests	---
	Torriorthents	35%	Mountain slopes	Lithic Torriorthents, loamy-skeletal, mixed (calcareous), thermic, 15 to 50% slopes.
	Haplargids	15%	Mountain slopes	Lithic Haplargids, loamy, mixed, thermic, 8 to 15% slopes.
14	Torriorthents	40%	Mountain slopes	Typic Torriorthents, loamy-skeletal, carbonatic, thermic, 8 to 30% slopes.
	Paleorthids	25%	Mountain slopes	Typic Paleorthids, loamy-skeletal, mixed (and carbonatic), thermic, 8 to 30% slopes.
	Rock outcrop (Limestone)	25%	Mountain slopes	---
43	Calciorthids	35%	Higher mountain slopes	Ustollic Calciorthids, loamy-skeletal, carbonatic, mesic, 4 to 30% slopes.
	Torriorthents	25%	Higher mountain slopes	Ustic Torriorthents, loamy-skeletal, carbonatic, mesic, 4 to 50% slopes.
	Haplustolls	25%	High mountain slopes	Lithic Haplustolls, loamy-skeletal, carbonatic, mesic, 8 to 50% slopes.

SOIL SERIES OF THE UNITED STATES, PUERTO RICO, AND THE VIRGIN ISLANDS: THEIR TAXONOMIC CLASSIFICATION

Soil Survey Staff, Soil Conservation Service, U.S. Department of Agriculture

This publication gives the present classification of all soil series that either have been mapped and described in published soil surveys in the United States, Puerto Rico, and the Virgin Islands, or that are currently in use and may later be described in published soil surveys.

The classification is given in two lists (computer printout). One is an alphabetical list of soil series that shows their classification or gives the reason why they are not classified. Conventional alphabetizing has been modified to facilitate computer programming. For example, the names St. Clair and Snake River are treated as single words and abbreviations are listed as they are written rather than as the words for which they stand. Thus, Snake River precedes St. Clair. In addition, a period or a space is equivalent to a character (a letter) and precedes the letter *a*. As a consequence, Snake River precedes Snakelum because Snakelum has no space or period before the letter *l* (see page 1-189).

The letters that precede some soil series names in this alphabetical listing have the following meanings:

I, an inactive series not currently used
P, a provisional classification
T, a tentative series

The series name is followed by the name of the state that contains the present type location of the series even though the name may have come originally from a different state.

Terms in parentheses immediately following or beneath some subgroup and family names indicate an alternate classification for the series. All such series are also identified with "P" for provisional classification, but not all series with provisional classification have an alternate classification.

The second list is of soil families and their included series. The families are arranged alphabetically by orders, suborders, and great groups. Subgroups are arranged alphabetically within each great group except that the typic subgroup is always listed first. Families within a subgroup are listed in approximate order of decreasing particle size. If several families have the same particle-size class, they are arranged alphabetically by mineralogy class, reaction class, temperature class, and so on. The letter "X" preceding a series name indicates that it is also a short name for the family. Two short names are indicated for a few families having series that are widely separated geographically. Short names are not given for families having only one series nor for families having only tentative series or series with provisional classifications.

The Soil Series

Soil surveys in the United States, which started in 1899, began describing and mapping soil series in 1903. The number of soil series grew rapidly during the first few years, but at that time the concept of what constitutes a series was different from the concept now accepted. For example, the initial concept of the Miami series included all soils developed in glacial drift, including those formed in loess. Under that concept, soils in the Miami series could have any texture and any drainage. They were identified from Kentucky to North Dakota and in all glaciated areas to the north and east. They included the Alfisols, Inceptisols, Mollisols, and Spodosols formed in loess, outwash, and till. Soil surveys published about 1903 reflect that concept, but it was soon changed.

By 1909,[1] Whitney wrote that color and structure determine a series and that texture determines the place of a soil within the series, namely, the type. New series were set apart on the basis of soil properties as rapidly as the significance of a property to the use of a soil was understood. Soils in the Marshall series were cut out of the Miami series because of their thick, dark surface horizon. The Marshall series at first also included soils formed in loess, till, and outwash. It was soon subdivided. The Carrington series as soils formed in till was one of the early series cut out of the Marshall. But the Carrington series was soon divided and redivided in turn. Soil maps published between 1910 and 1920 show soils in the Carrington series in places where now soils in more than a dozen series are mapped.

For the first three decades of soil surveys, series were defined partly by the "soil province" in which they occurred. The soil provinces were large areas in which the geologic history was reasonably similar. Examples are the Atlantic and Gulf Coastal Plain and the Glacial and Loessial Province. The first publication in which the soils of the United States were described was issued in 1909. About 230 series and 700 types were listed. The

[1] Whitney, Milton. Soils of the United States. U.S. Dep. Agr. Bur. Soils Bull. 55. 1909.

Table 1.--*Orders: The names and their meanings*

Order name	Formative element	Principal diagnostic property(ies) (simplified definitions)
Alfisols	alf	Mineral soils; relatively low in organic matter; relatively high base saturation; an illuvial horizon of silicate clays; moisture available to mature a crop.
Aridisols	id	Mineral soils; relatively low in organic matter; inadequate moisture to mature a crop without irrigation in most years; some pedogenic horizons.
Entisols	ent	Mineral soils; weak or no pedogenic horizons; no deep wide cracks in most years.
Histosols	ist	Organic in more than half of upper 80 cm.
Inceptisols	ept	Mineral soils; some pedogenic horizons and some weatherable minerals; moisture available to mature a crop in most years; no horizon of illuvial clays; relatively low in either organic matter or base saturation, or in both.
Mollisols	oll	Mineral soils; thick dark surface horizon, relatively rich in organic matter; high base saturation throughout; no deep wide cracks in most years.
Oxisols	ox	Mineral soils; no weatherable minerals; inactive clays; no illuvial horizon of silicate clays.
Spodosols	od	Mineral soils; an illuvial horizon of amorphous aluminum and organic matter, with or without amorphous iron.
Ultisols	ult	Mineral soils; an illuvial horizon of silicate clays; low base saturation; moisture available to mature a crop in most years.
Vertisols	ert	Clayey soils; deep wide cracks at some time in most years.

next publication,[2] issued in 1913, listed about 550 series that were divided into one or two thousand types and phases.

By the 1930's, Marbut[3] developed the first hierarchal classification of soils, but only a few series were related to the great soil groups. At that time there were about 1,500 series divided into approximately 5,000 types.

In 1938 another system of classification was published,[4] and again most of the series were not related to the great soil groups. At this time there were about 2,000 series divided into about 6,000 types. By 1964, about 8,000 series had been recognized.

In 1965, after about 15 years of study, the National Cooperative Soil Survey began using the present taxonomy. Some 10,466 series are listed in this publication, nearly 1,000 of which are inactive. Some of the older series that were broadly defined are not classified. The classification for some series is marked as provisional, but most classifications are not. The reader who uses this book as a reference must understand that:

1. The classification of all series is provisional to some extent and changes can be expected as we learn more about the soils. And, as we learn, the taxonomy itself will change. This is the first publication of the classification of the soil series in the United States, and some misunderstandings and mistakes are unavoidable among a large staff that is widely scattered. Any series classification subsequent to the date of this publication should take precedence if it differs from the classification given here.

2. The classification reflects the current concept of a series, which is not necessarily the same concept that was held in previous years. Series names in earlier publications do not necessarily reflect the present concepts. Generally, the older the publication, the less likely is the concept to be the same.

The Meanings in the Names

The names in the alphabetical list, pages 1-1 through 1-228, give the family classification of each soil series. The families that have been recognized and their included series are named in the second list, pages 2-1 through 2-132. A series name is an abstract name, usually taken from the name of a town or landscape feature near the place where the series was first described, but the names of the families are descriptive if the

[2] Marbut, C.F., Bennett, H.H., Lapham, J.E. and Lapham, M.H. Soils of the United States. U.S. Dep. Agr. Bur. Soils Bull. 96. 1913.

[3] Marbut, C.F. Soils of the United States. *In* Atlas of American Agriculture, pt. 3. U.S. Dep. Agr. 1935.

[4] Baldwin, M., Kellogg, Charles E., and Thorp, James. Soil Classification. *In* 1938 Yearbook of Agriculture, p. 979-1001. U.S. Dep. Agr. 1938.

reader understands the meanings of the formative elements in the names. Complete definitions are given in "Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys" (in press). The user of these lists who does not need precise definitions may still find it helpful to have a general notion of some of the more important properties of a soil series or family.

The names of the taxa have been coined by using, to the extent possible, Greek and Latin roots that are familiar through their use in many common words. Derivations are given in "Soil Taxonomy." The family name identifies all the higher categories of classification of the family, namely, subgroup, great group, suborder, and order. For example, the Abac series is in the *loamy, mixed (calcareous), frigid, shallow* family of Typic Ustorthents (fig. 1). This name gives us the following information about the Abac soils:

> They have no significant pedogenic horizons and only moderate to small amounts of organic matter (from *ent*).
>
> They are on recent slopes, subject to erosion (from *orth*).
>
> They are well drained and are dry for a significant part of the year but are dry for less than half of the growing season (from *ust*).
>
> There is soft rock, probably calcareous, within 50 cm of the surface (from *shallow* and *calcareous*).
>
> The soils are warm in summer and frozen in winter (a snow cover is unlikely for soils in an ustic great group), and the mean annual soil temperature is between 0° and 8° C (from *frigid*).
>
> The mineralogy is not dominated by any one mineral; it is a mixture of several, including some $CaCO_3$ but less than 40 percent (from *mixed, calcareous*).
>
> The clay percentage is less than 35, and the texture is finer than loamy sand (from *loamy*).

Abac soils, having such a combination of properties, are not likely to be cultivated. They can produce a moderate amount of forage for grazing in late spring and early summer.

The Nomenclature of the Soil Taxonomy

Names from all categories higher than the series are used in constructing a complete family name. It is made up of descriptive family modifiers followed by a subgroup name, which is a composite of the names of a suborder and great group and which ends in a syllable that identifies the soil order. For example, the Abac soils are in the subgroup of *Typic Ustorthents* of the great group of Ustorthents. *Ustorthents* are a great group of the suborder of Orthents. *Orthents* are a suborder of the order of *Entisols*. The names of the suborder, great group, and subgroup all end in the syllable *ent*, which is the "formative element" in the name of the order (*Ent*isol). In the name of an order the syllable that is the formative element is the last syllable beginning with a vowel and ending with the last consonant preceding the vowel that connects the suffix *sol*. All names of orders end in *sol*. The italicized syllables that follow are examples of formative elements in the names of orders: Incept*i*sols, Moll*i*sols, Spod*o*sols, Vert*i*sols, etc.

Orders

There are ten soil orders. Their names can be recognized as such because each ends, as stated, in *sol* (L. *solum*, soil), which is preceded by *o* as the connecting vowel in names coined from Greek roots or by *i* in names coined from roots of other origin.

In table 1, the names of the ten soil orders (column 1) and the formative element in each of the names (column 2) are given. Also listed are simplified definitions of the principal diagnostic properties of the soils in each order (column 3).

Suborders

The name of a suborder has exactly two syllables: Its last syllable is the formative element from the name of the order. The first syllable connotes additional diagnostic properties of the soils in the suborders. Thus, an Entisol that has an aquic moisture regime throughout is called an Aquent (L. *aqua*, water, plus *ent* from Entisols); an Entisol that consists of very young sediments is called a Fluvent (L. *fluvius*, river, plus *ent* from Entisols).

Table 2 lists 24 first formative elements of suborder names and the simplified explanations of their connotations.

Great groups

The name of a great group has three or four syllables. The last two syllables are the name of the suborder. The first syllable in the name of a great group connotes additional diagnostic properties of the soils in that great group. The second syllable generally is formed when a vowel is added to connect the first syllable to the last two syllables (the name of the suborder). For example, an Aridisol in the suborder of Argids and in which

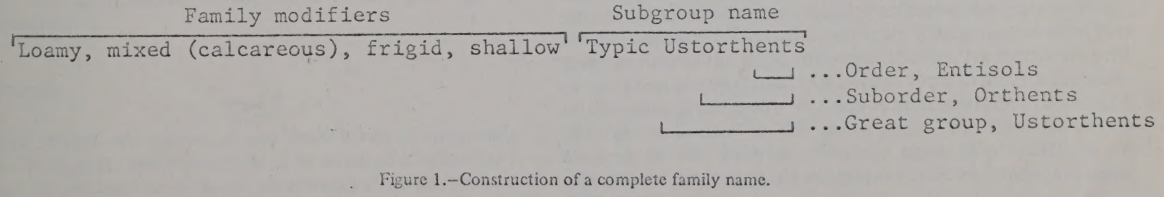

Figure 1.–Construction of a complete family name.

Table 2. *Suborders: First formative elements and their connotations*

First formative element	Connotation (simplified explanation)	First formative element	Connotation (simplified explanation)
alb	A nearly white eluvial horizon near the surface, reflecting wetness.	orth ...	The most representative, true: Orthids have no illuvial B horizon of silicate clays; Orthents are on recently eroded slopes; Orthox have a short dry season or no dry season: Orthods have a B horizon that contains iron, aluminum, and humus.
and....	Presence of appreciable allophane.	plagg ..	A surface mantle >50 cm thick of materials that have been added by continued manuring.
aqu....	A soil that is very wet or that has been artificially drained.	psamm .	Sandy texture, sand, or loamy sand, to a depth of 1 m or more or to rock.
ar.....	A soil having only fragments of horizons due to mixing by men.	rend ...	A shallow (<50 cm deep) dark soil on highly limy material (>40% $CaCO_3$ equivalent).
arg	A soil having an illuvial horizon of silicate clays.	sapr ...	Composed mostly of highly decomposed plant materials.
bor....	A cool or cold soil, mean annual soil temperature <8° C.	torr ...	Inadequate moisture to mature a crop without irrigation.
ferr ...	Presence of appreciable free iron.	trop ...	No distinct winter or summer; moist and tropical.
fibr ...	Composed mostly of undecomposed plant fibers.	ud	Moist but not wet; dry for short periods or not at all.
fluv ...	Composed of recent alluvium.	umbr ..	A thick, acid, dark-colored surface horizon.
fol	Composed of leaves, twigs, and branches; all in various stages of decomposition.	ust	Dry for long periods but moist in a growing season for 90 days or more in most years; droughts common.
hem ...	Composed of partly decomposed plant materials.	xer	A soil in midlatitudes that is reliably moist in winter and dry in summer; reflecting Mediterranean climate.
hum ...	Presence of appreciable humus.		
ochr ...	A surface horizon that is either light in color or low in organic matter, or both.		

there are significant amounts of exchangeable sodium (*natr*, see table 3) is called a Natrargid (a three-syllable name containing no connecting vowel); an Entisol in the suborder of Fluvents that has a cryic temperature regime is called a Cryofluvent, a four-syllable name (Gr. *kyros*, icy cold, expressed by the formative element *cry*; plus the vowel *o* preceding Fluvent). In some four-syllable names, however, both the first and second syllables are formative elements of names of great groups (see table 3 for construction of the name of the great group Nadurargids).

Subgroups

Great groups are separated into three kinds of subgroups: Typic, intergrade, and extragrade. The name of a subgroup is formed by placing one or more adjectives before the name of the relevant great group.

A *typic subgroup* represents the central concept of its great group. A soil in a typic subgroup, however, is not necessarily more extensive than the other kinds of soil in the same great group.

An *intergrade subgroup* has the definitive properties of the great group whose name it carries as a substantive. It also has some of the properties of another taxon or more than one other taxon—an order, a suborder, or a great group. The adjective or adjectives in the intergrade subgroup name are formed from the names of the other taxon or taxa. Formative elements normally are not repeated. Thus, if a soil is an intergrade between two great groups in the same suborder, the first formative element of one great group is used in adjective form to modify the name of the other great group. If a soil is an intergrade to a soil of a different suborder in the same order, the final formative element in the different suborder name is not used as an adjective in the intergrade subgroup name. Following are some examples.

Table 3. -*Great groups: First formative elements and their connotations*

First formative element	Connotation (simplified explanation)
acr	Extremely low CEC in clay fraction.
agr	Having an illuvial horizon of clay and humus formed under cultivation.
alb	A nearly white eluvial horizon near the surface, reflecting wetness.
and	Presence of appreciable allophane.
arg	A soil having an illuvial horizon of silicate clays.
bor	A cool or cold soil, mean annual soil temperature $< 8°$ C.
calc	A soil that is calcareous throughout and that has a horizon with an appreciable accumulation of lime.
cambb	A soil having an altered but not illuvial B horizon.
chrom	Brownish or reddish color.
cry	A soil that is relatively cold even in summer.
dur	A soil having a hardpan cemented with silica.
dys, dystr	Low base saturation.
[illegible], eutr	High base saturation.
ferr	Presence of appreciable free iron.
frag	Presence of a fragipan.
fragloss	(See *frag* and *gloss*.)
gibbs	Presence of gibbsite in sheets or nodules.
gloss	Presence of gray eluvial tongues in an illuvial horizon of silicate clay.
hal	Wet and somewhat salty.
hapl	The simplest set of horizons.
hum	Presence of appreciable amount of humus.
hydr	Presence of excess water.
luv	A soil having a horizon of illuvial humus.
med	A soil of midlatitudes.
nadur	(See *natr* and *dur*.)
natr	Presence of significant amounts of exchangeable sodium or of magnesium and sodium.
ochr	A surface horizon that is either light in color or low in organic matter, or that is both.
pale	A soil having horizons that have more than normal development.
pell	A soil that has low chroma.
plac	Presence of a thin (a few mm) pan, cemented by iron or by iron and humus.
plagg	A surface mantle, > 50 cm thick, of materials that have been added by continued manuring.
plinth	Presence of large amounts of plinthite, an iron-rich material that hardens irreversibly on exposure.
psamm	Sandy texture, a sand or loamy sand, to a depth of 1 m or more.
quartz	More than 95 percent quartz.
rhod	Dark colors due to high iron content, generally dark red.
sal	Presence of a horizon with > 2 percent salt.
sider	Presence of appreciable free iron.
sphagn	Mostly sphagnum.
sulf	Presence of appreciable shallow sulfides or products of their oxidation.
torr	Inadequate moisture to mature a crop without irrigation.
ud	Moist but not wet, and dry for short periods or not at all.
umbr	A thick, acid, dark-colored surface horizon.
ust	Dry for long periods but moist in a growing season for 90 days or more in most years; droughts common.
verm	Intensively mixed by animals, chiefly worms and their predators.
vitr	Large amounts of glass.
xer	A soil of midlatitudes that is reliably moist in winter and dry in summer, reflecting Mediterranean climate.

Name of great group	*Taxon to which it intergrades*	*Subgroup name*
Haploxeroll	Calcixeroll	Calcic Haploxeroll
	Aquoll	Aquic Haploxeroll
	Fluvaquent	Fluvaquentic Haploxeroll
	Fluvent	Fluventic Haploxeroll
	Orthent	Entic Haploxeroll (not orthentic)

The name of any taxon, converted to an adjective, can be used in the name of an intergrade subgroup.

An *extragrade subgroup* has aberrant properties that do not represent intergrades to any known kind of soil. Hard rock, for example, is not considered to be soil. Consequently, a soil with underlying hard rock at a depth of <50 cm is placed in a *lithic* subgroup. A permanently frozen layer, permafrost, below the soil is the basis for placing a soil in a *pergelic* subgroup. These subgroups, in a sense, are made up of intergrades to "not soil." A soil at the base of a slope may accumulate sediments slowly, producing in time only a very thick dark-colored A1 horizon. Such a soil is placed in a *cumulic* subgroup because there is no known thick soil that consists of only an A1 horizon. The adjectives used in forming the names of extragrade subgroups and their meanings are given in table 4.

Following are examples of how the nomenclature of the taxonomy is applied in forming names from order through subgroup:

Subgroup	*Great group*	*Suborder*	*Order*
Typic Ustorthents	Ustorthents	Orthents ..	Entisols
Aquic Fragiudalfs	Fragiudalfs	Udalfs	Alfisols
Typic Fragiaqualfs.....	Fragiaqualfs	Aqualfs ...	Alfisols
Terric Borohemists.....	Borohemists.....	Hemists ...	Histosols
Ustollic Calciorthids	Calciorthids	Orthids ...	Aridisols

Families of mineral soils

A complete family name consists of a subgroup name preceded by a few, usually three, modifiers that narrow the range of properties enough to permit general statements about use and management of the soils. Modifiers in a family name of mineral soils represent the following differentiae, listed according to their sequence in the name.

Particle-size class
Mineralogy class
Calcareous and reaction classes
Soil temperature class
Soil depth class
Soil slope class
Soil consistence class
Coatings
Class of permanent cracks

Table 4.—*Extragrade subgroups: Adjectives used in the names and their meanings*

Adjective	Meaning	Adjective	Meaning
abruptic	A large difference in percentage of clay between an eluvial horizon and an illuvial horizon without a significant transitional horizon.	lithic	Hard rock within 50 cm of the surface.
aeric[1]	Browner and better aerated than typic.	pergelic	Presence of permafrost.
anthr	A manmade dark-colored surface horizon.	petrocalcic ...	An indurated horizon of lime accumulation.
arenic.....	Sandy eluvial horizons (sand or loamy sand), mostly between 50 cm and 1 m thick.	petroferric ...	A shallow layer of ironstone.
cumulic	An overthickened epipedon rich in humus.	pachic	A thick dark surface horizon.
glossic	Tongued eluvial and illuvial horizons.	plinthic[1].....	Presence of small amounts of plinthite, an iron-rich material that hardens irreversibly on exposure.
grossarenic ...	Sandy eluvial horizons (sand or loamy sand) >1 m thick.	ruptic.....	Intermittent horizons.
hydric	Organic soil floating on water if used in name of a Histosol.	sulfic	Presence of deep sulfides or moderate amounts if shallow, or products of sulfide oxidation.
leptic	Thin soil horizons.	superic	Very shallow plinthite.
limnic.....	Organic soil with basal layer of marl, diatoms, or sedimentary peat.	terric	A mineral substratum in an organic soil.
		thapto[1].....	A buried soil.

[1] Not strictly an extragrade. Name is used to indicate a special departure from the typic subgroup.

The control section

Classes of particle size are used to describe material in the control section. The class named is that of the weighted average of the control section unless two strongly contrasting classes are present. Then both classes are named. In soils that do not have an argillic horizon, the control section normally extends from a depth of 25 cm to 100 cm. In soils that have an argillic horizon, the control section normally is the upper 50 cm of the argillic horizon if the horizon is >50 cm thick or is the whole argillic horizon if the horizon is <50 cm thick. If there is rock or permafrost at a more shallow depth, the control section stops at the rock or 25 cm below the top of the permafrost. The same control section is used for classes of mineralogy, but strongly contrasting classes are not used. The mineralogy of the upper part of the control section is named.

Particle-size classes

Particle size refers to grain-size distribution of the whole soil and is not the same as texture, which refers to the fine-earth fraction. The fine-earth fraction consists of the particles that have a diameter <2 mm. Particle-size classes are a kind of compromise between engineering and pedologic classifications. In engineering classifications, the limit between sand and silt is a diameter of 74 microns; in pedologic classifications, the limit is a diameter of either 50 or 20 microns. Engineering classifications are based on percentages by weight in the fraction <74 mm in diameter, and textural classes are based on percentages by weight in the fraction <2 mm in diameter.

The very fine sand separate (diameter between 0.05 mm and 0.1 mm) is split in engineering classifications. In defining particle-size classes, much the same split is made but in a different manner. A soil that has a texture of fine sand or loamy fine sand normally has an appreciable content of very fine sand, but the very fine sand fraction is mostly coarser than 74 microns. A silty sediment, such as loess, may also have an appreciable component of very fine sand, but most of the very fine sand is finer than 74 microns. So, in particle-size classes, the very fine sand is allowed to "float." It is treated as sand if the texture is fine sand, loamy fine sand, or coarser. It is treated as silt if the texture is very fine sand, loamy very fine sand, sandy loam, silt loam, or finer.

No single set of particle-size classes seems appropriate as family differentiae for all kinds of soils. The classes listed in table 5 provide for a choice of either 7 or 11 particle-size classes. This choice permits relatively fine distinctions in soils if particle size is important and permits broader groupings if the particle size is not susceptible to precise measurement or if using narrowly defined classes produces undesirable groupings. Thus in some families the term "clayey" indicates that there is 35 percent or more clay in defined horizons, but in other families the term "fine" indicates that the clay fraction constitutes 35 through 59 percent of the fine earth of the horizons, and the term "very-fine" indicates 60 percent or more clay. The term "rock fragments" refers to particles 2 mm in diameter or larger and includes all sizes that have horizontal dimensions less than the size of a pedon. It is not the same as the term "coarse fragments," which excludes stones and boulders larger than about 25 cm. The term "fine earth" refers to particles smaller than 2 mm in diameter.

There are three situations in which particle-size class names are not used. In the first situation, the name is redundant. Psamments and Psammaquents, by definition, are sandy, and no particle-size class name is needed or used in the family name.

In the second situation, particle size is meaningless because, presumably, the soil consists of a mixture of discrete mineral particles and of gels. The concept of either texture or particle size is not applicable to a gel, particularly if the gel cannot be dispersed. Consequently, particle-size class names are not used if the soil is mostly glass or if the exchange complex is dominated by amorphous materials, as is true of Andepts by definition. In families of Andepts and Andaquepts, in most andic subgroups of Inceptisols and in andeptic and andaqueptic subgroups of other orders, and in cindery and ashy families of Entisols and Aridisols, particle-size class names as such are not used for the part of the soil that cannot be dispersed.

In the third situation, the organic-matter content is high and particle size has only limited relation to the physical and chemical properties of the soils. This seems to be normal in soils that have both a cryic temperature regime and a spodic horizon. Therefore, particle-size class names are not used for the spodic horizons[5] of Cryaquods, Cryohumods, Cryorthods, or Cryic Placohumods.

The terms in table 6 are substituted for particle-size class names for the taxa that have been listed under the second and third situations unless the particle-size modifier is redundant. They reflect a combination of particle size and mineralogy, and take the place of both.

Mineralogy classes

Mineralogy classes are based on the approximate mineralogical composition of selected size fractions of the same segment of the soil (control section) that is used for application of particle-size classes.

Contrasting mineralogy modifiers are not recognized except where substitute modifiers have been used in place of particle-size class modifiers (table 6). In those soils there is an overlay of ash or cinders or an upper medial or thixotropic layer, and the ashy, cindery, medial, or thixotropic layer extends at least 10 cm into the upper part of the control section. In identifying and naming the contrasting mineralogy modifiers in families of those soils, the seven particle-size classes are used to describe the lower part of the section. For example, a pair of contrasting

[5] Particle-size class names are applied to other spodic horizons but with reservations. Somewhat different classes probably should be used for most families of Spodosols, but data are too few to permit the testing of alternatives. Some series that otherwise would be reasonably homogeneous are split at the family level by the particle-size classes. Soils in these series have appreciable but not very large amounts of organic matter in the spodic horizon.

Table 5.—*Families: Modifiers that express particle-size classes in names*

Class	Definition
1. Fragmental	Stones, cobbles, gravel, and very coarse sand particles; too little fine earth to fill interstices >1 mm in diameter.
2. Sandy-skeletal	Rock fragments 2mm or coarser make up 35 percent or more by volume; enough fine earth to fill interstices >1 mm; the fraction < 2 mm is sandy as defined for particle-size class 5.
3. Loamy-skeletal	Rock fragments make up 35 percent or more by volume; enough fine earth to fill interstices >1 mm; the fraction < 2 mm is loamy as defined for particle-size class 6.
4. Clayey-skeletal	Rock fragments make up 35 percent or more by volume; enough fine earth to fill interstices >1 mm; the fraction finer than 2 mm is clayey as defined for particle-size class 7.
5. Sandy	The texture of the fine earth is sand or loamy sand but not loamy very fine sand or very fine sand; rock fragments make up < 35 percent by volume.
6. Loamy	The texture of the fine earth is loamy very fine sand, very fine sand, or finer, but the amount of clay[1] is <35 percent; rock fragments are < 35 percent by volume.
a. Coarse loamy	By weight, 15 percent or more of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; < 18 percent clay in the fine-earth fraction.
b. Fine-loamy	By weight, 15 percent or more of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; 18 through 34 percent clay in the fine-earth fraction (< 30 percent in Vertisols).
c. Coarse-silty	By weight, < 15 percent of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; < 18 percent clay in the fine-earth fraction.
d. Fine-silty	By weight, < 15 percent of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; 18 through 34 percent clay in the fine-earth fraction (< 30 percent in Vertisols).
7. Clayey	The fine earth contains 35 percent or more clay by weight, and rock fragments are < 35 percent by volume.
a. Fine	A clayey particle-size class for soils having 35 through 59 percent clay in the fine-earth fraction (30 through 59 percent for Vertisols).
b. Very-fine	A clayey particle-size class for soils having 60 percent or more clay in the fine-earth fraction.

[1] Carbonates of clay size are not considered to be clay but are treated as silt in all particle-size classes. If the ratio of 15-bar water to clay is 0.6 or more in half or more of the control section, for this purpose the percentage of clay is considered to be 2.5 times the percentage of 15-bar water.

Table 6.--*Families: Modifiers that substitute in some names for other adjectives that connote particle-size and mineralogy classes*

Modifier	Meaning
Cindery	Sixty percent or more of the whole soil (by weight[1]) is volcanic ash, cinders, and pumice; 35 percent or more is cinders that have a diameter of 2 mm or more.
Ashy	Sixty percent or more of the whole soil (by weight) is volcanic ash, cinders, and pumice; < 35 percent (by volume) is 2 mm in diameter or larger.
Ashy-skeletal	Thirty-five percent or more (by volume) is rock fragments other than cinders; the fine-earth fraction is otherwise ashy.
Medial	Less than 60 percent of the whole soil (by weight) is volcanic ash, cinders, and pumice; < 35 percent (by volume) is 2 mm in diameter or larger; the fine-earth fraction is not thixotropic; the exchange complex is dominated by amorphous materials.
Medial skeletal	Thirty-five percent or more (by volume) is rock fragments other than cinders 2 mm in diameter or larger; the fine-earth fraction is otherwise medial.
Thixotropic	Less than 35 percent (by volume) has diameter of 2 mm or larger; the fine-earth fraction is thixotropic; the exchange complex is dominated by amorphous materials.
Thixotropic-skeletal	Thirty-five percent or more (by volume) is rock fragments other than cinders 2 mm in diameter or larger; the fine earth fraction is otherwise thixotropic.

[1] Percentages by weight in these definitions are estimated from grain counts; generally a count of one or two dominant size fractions of the conventional mechanical analysis is enough for placement of soil.

layers is named "medial over loamy, mixed," not "medial over coarse-loamy, mixed."

If there are layers of contrasting particle size in the control section, the mineralogy class of the upper part of the control section is definitive of the family mineralogy. For example, if there is fine-loamy material of mixed mineralogy over sandy material that is siliceous, the proper modifiers describing the family are "fine-loamy over sandy, mixed," not "fine-loamy, mixed, over sandy, siliceous."

Table 7 is a key to mineralogy classes, not a set of complete definitions. Mineral soils are placed in the first mineralogy class of the key that accommodates them although they also may seem to meet the requirements for other mineralogy classes. Substitute terms that connote both particle size and mineralogy are based on combined texture, consistence, and mineralogy classes and are used to indicate important variations in Andaquepts; Andepts; andic, andaqueptic, and andeptic subgroups; cryic great groups of Spodosols; and cindery and ashy families of Aridisols and Entisols. Mineralogy classes are not named for Calciaquolls because the effect of the carbonates overshadows other differences in mineralogy, and they are not named for Quartzipsamments, which, by definition, are siliceous.

It is recognized that normally it is impossible to be certain of the percentages of the various kinds of clay minerals. Quantitative methods of identification are still subject to change. Although much progress has been made in the past few decades, an element of judgment enters into any estimation of the percentages. All the evidence does not need to come from X-ray, surface, and DTA determinations. Other physical and chemical properties suggest the mineralogy of many clayey soils. Changes in volume, cation-exchange capacity, and consistence are useful in estimating the nature of clay.

The description of clay mineralogy in naming families of clayey soils is based on the weighted average of the control section.

Calcareous and reaction classes

The presence or absence of carbonates and the reaction are discussed together because they are so intimately related. A calcareous horizon cannot be strongly acid. Calcareous classes are applied to the section between depths of 25 and 50 cm or between a depth of 25 cm and a lithic or paralithic contact that is below a depth of 25 cm but not as deep as 50 cm, or to some part of the soil above a lithic or paralithic contact that is shallower than 25 cm. Two classes, calcareous and noncalcareous, are used in selected taxa. The definitions follow.

Calcareous.—The fine-earth fraction effervesces in all parts with cold dilute HCl.

Noncalcareous.—The fine-earth fraction does not effervesce in all parts with cold dilute HCl. The term "noncalcareous" is not used as a part of a family name.

Table 7.—*Key to mineralogy classes*

Class	Definition	Determinant size fraction
	CLASSES APPLIED TO SOILS OF ANY PARTICLE–SIZE CLASS	
Carbonatic	More than 40 percent by weight carbonates (expressed as $CaCO_3$) plus gypsum, and the carbonates are > 65 percent of the sum of carbonates and gypsum.	Whole soil, particles <2 mm, in diameter, or whole soil < 20 mm, whichever has higher percentage of carbonates plus gypsum.
Ferritic	More than 40 percent by weight iron oxide extractable by citrate-dithionite, reported as Fe_2O_3 (or 28 percent reported as Fe).	Whole soil, particles <2 mm in diameter.
Gibbsitic	More than 40 percent by weight hydrated aluminum oxides, reported as gibbsite and boehmite.	Whole soil, particles <2 mm in diameter.
Oxidic	Less than 90 percent quartz; < 40 percent any other single mineral listed subsequently; and the ratio, percent extractable iron oxide plus percent gibbsite to percent clay[1], is 0.20 or more. That is, $\frac{\text{extractable } Fe_2O_3 \text{ (pct.)} + \text{gibbsite (pct.)}}{\text{clay(pct.)}^1} \geq 0.20$	For quartz and other minerals, fraction 0.02 to 2 mm in diameter; for ratio of iron oxide and gibbsite to clay, whole soil < 2 mm.
Serpentinitic	More than 40 percent by weight serpentine minerals (antigorite, chrysotile, fibrolite, and talc).	Whole soil, particles <2 mm in diameter.
Gypsic	More than 40 percent by weight of carbonates (expressed as $CaCO_3$) plus gypsum, and the gypsum is > 35 percent of the sum of carbonates and gypsum.	Whole soil, particles <2 mm in diameter, or whole soil < 20 mm, whichever has higher percentage of carbonates plus gypsum.
Glauconitic	More than 40 percent glauconite by weight.	Whole soil, particles <2 mm in diameter.
	CLASSES APPLIED TO SOILS THAT HAVE A SANDY, SANDY-SKELETAL, LOAMY, OR LOAMY-SKELETAL PARTICLE-SIZE CLASS	
Micaceous	More than 40 percent mica by weight.[2]	0.02 to 20 mm.
Siliceous	More than 90 percent by weight[2] of silica minerals (quartz, chalcedony, or opal) and other extremely durable minerals that are resistant to weathering.	0.02 to 2 mm.
Mixed	All others that have < 40 percent of any one mineral other than quartz or feldspars.	0.02 to 2 mm.
	CLASSES APPLIED TO SOILS THAT HAVE A CLAYEY PARTICLE-SIZE CLASS	
Halloysitic	More than half halloysite[3] by weight and smaller amounts of allophane or kaolinite or both.	< 0.002 mm.
Kaolinitic	More than half kaolinite, tabular halloysite, dickite, and nacrite by weight and smaller amounts of other 1:1 or nonexpanding 2:1 layer minerals or gibbsite.	< 0.002 mm.
Montmorillonitic	More than half montmorillonite and nontronite by weight or a mixture that has more montmorillonite than any other one clay mineral.	< 0.002 mm.
Illitic	More than half illite (hydrous mica) by weight and commonly > 4 percent K_2O.	< 0.002 mm.
Vermiculitic	More than half vermiculite by weight or more vermiculite than any other one clay mineral.	< 0.002 mm.
Chloritic	More than half chlorite by weight or more chlorite than any other clay mineral.	< 0.002 mm.
Mixed	Other soils.[4]	< 0.002 mm.

[1] Percentage of clay or percentage of 15-bar water times 2.5, whichever is greater, provided the ratio of 15-bar water to clay is 0.6 or more in half or more of the control section.

[2] Percentages by weight are estimated from grain counts. Usually, a count of one or two of the dominant size fractions of a conventional mechanical analysis is sufficient for placement of the soil.

[3] Halloysite as used here includes only the tubular forms. What has been called tabular halloysite is grouped here with kaolinite.

[4] Sepiolitic, defined as containing more than half by weight of sepiolite, attapulgite, and palygorskite, should be named if found.

It should be noted that a soil containing dolomite is calcareous and that effervescence of dolomite, when treated with cold dilute HCl, is slow.

Reaction classes are applied to the control section that is defined for particle-size classes. Two classes, acid and nonacid, are used in selected taxa. The definitions follow.

Acid.—The pH is < 5.0 in 0.01 M $CaCl_2$ (2:1) throughout the control section (about 5.5 in H_2O, 1:1).

Nonacid.—The pH is 5.0 or more in 0.01 M $CaCl_2$ (2:1) in at least some part of the control section. The term "nonacid" is not used in family names of calcareous soils.

Reaction-class modifiers are used only in names of families of Entisols and Aquepts; they are not used in names of sandy, sandy-skeletal, and fragmental families of these taxa, nor are they used in names of Sulfaquepts and Fragiaquepts and families that have carbonatic or gypsic mineralogy.

Calcareous-class modifiers are used, if appropriate, in the names of the same taxa as reaction classes and, in addition, are used in families of Aquolls except for Calciaquolls and for Aquolls that have an argillic horizon. Calcareous reaction-class modifiers are not used in family names of soils that have carbonatic or gypsic mineralogy. A calcareous soil is never acid. Calcareous therefore implies nonacid, and both modifiers are not used in the family name because nonacid would be redundant. Similarly, noncalcareous would be redundant in family names of acid soils.

Soil temperature classes

Soil temperature classes, as named and defined here, are used as family differentiae in all orders. The class names are used as family name modifiers unless the name of a higher taxon carries the same limitation. Thus, frigid is implied in all boric suborders and cryic great groups and is redundant in the name of a family.

The Celsius (centigrade) scale is the standard. Approximate Fahrenheit equivalents are indicated parenthetically. It is assumed that the temperature is that of a soil that is not being irrigated.

For soils in which the difference is 5° C (9° F) or more between mean summer (June, July, and August in the northern hemisphere) and mean winter (December, January, and February in the northern hemisphere) soil temperatures at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower, the following classes, defined in terms of the mean annual soil temperature are used.

Frigid.—Less than 8° C (47° F).
Mesic.—From 8° to 15° C (47° to 59° F).
Thermic.—From 15° to 22° C (59° to 72° F).
Hyperthermic.—More than 22° C (72° F).

For soils in which the difference is less than 5° C (9° F) between mean summer and mean winter soil temperature at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower, the following classes, defined in terms of the mean annual soil temperature are used.

Isofrigid.—Less than 8° C (47° F).
Isomesic.—From 8° to 15° C (47° to 59° F).
Isohyperthermic.—More than 22° C (72° F).

The appropriate limit between isofrigid and isomesic cannot be tested in the United States and probably will need to be revised.

Other characteristics

Several soil characteristics other than those already discussed must be considered in particular taxa to provide reasonable groupings of series into families. Some of these seem to be logical family criteria. Others probably should have been used in higher categories, but the lack of information about them makes it much safer to use them as family differentiae at this time. These characteristics include soil depth, soil slope, soil consistence, moisture equivalent, and permanent cracks.

Soil depth classes.—Classes of shallow and deep soils may be needed at the family level in all orders of mineral soils. Some distinctions in depth are made in great groups and in arenic and lithic subgroups, but some other soils should also be grouped in families according to depth. Some soils have a paralithic contact over soft rock such as clay shale that is too compact for penetration by roots. The classes of soil depth follow.

Micro. Less than 18 cm through diagnostic horizons. Used in cryic great groups but not in pergelic subgroups or in Entisols.

Shallow. Two depths are considered shallow.

1. Less than 50 cm to the upper boundary of a petrocalcic horizon or to a paralithic or a petroferric contact. Used in all great groups of Entisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, and Ultisols, except pergelic subgroups of the cryic great groups (Cryaquepts, Cryumbrepts, Cryorthods, and so on). Note that lithic subgroups are also shallow, but the adjective "shallow" in a family name for them is redundant.
2. Less than 1 m to a lithic or paralithic or a petroferric contact. Used in families of Oxisols.

Soil slope or shape.—Soils of aquic great groups normally have level or concave surfaces. They are mainly in places where ground water saturates the soil during some period of the year. A few, however, are on the sides of slopes where water cannot stand and are kept wet by more or less continuous precipitation and by seepage of water from higher areas. A very few aquic soils are kept wet by hydrostatic pressure. No consistent internal morphologic clues have yet been found that distinguish those sloping aquic soils if the dissolved oxygen content is low, but they generally are easily recognized in the field from their position in the landscape. It is proposed, therefore, in aquic great groups, particularly in Aquolls and Aqualts, to use the shape of the soil as a family differentia. Classes of level and sloping soils, as these classes are defined in the Soil Survey Manual (1951), seem adequate. It may be necessary to use slope classes as family differentiae in other orders, but they should not be used as differentiae for families of Aquods or Albaqualfs. If no slope modifier is used in the family name, "level" is assumed in families of aquic soils.

Soil consistence.—Some cemented horizons, for example, a duripan, are differentiae in the classification in categories

above the family. Others, such as a cemented spodic horizon (ortstein) are not, but no single family should include both soils that have a continuous, shallow cemented horizon and soils that do not. In Spodosols, in particular, a cemented spodic horizon needs to be used as a family differentia. The following classes of consistence are defined for Spodosols.

Ortstein. All or part of the spodic horizon is at least weakly cemented, when moist, into a massive horizon that is present in more than half of each pedon.

Noncemented. The spodic horizon, when moist, is not cemented into a massive horizon in as much as half of each pedon.

Cementation of a small volume into shot or concretions does not constitute cementation that forms a massive horizon. The name of a family of noncemented Spodosols normally does not have a modifier that implies lack of cementation. The name of a family of cemented Spodosols contains the modifier "ortstein."

A cemented calcic or gypsic horizon is not identified in a family name. Many calcic and some gypsic horizons are weakly cemented and some are indurated. The recognition of a petrocalcic or petrogypsic horizon is expected to meet most, if not all, the needs for recognition of cementation in those horizons. Taxa of these cemented soils are not named at the family level.

Coatings.—Despite the emphasis given to particle-size classes in the taxonomy, variability remains in the sandy particle-size class, which takes in sands and loamy sands. Some sands are very clean, almost completely free of silt and clay. Others are mixed with appreciable amounts of finer grains. A moisture equivalent of 2 percent makes a reasonable division of the sands at the family level. Two classes of Quartzipsamments are defined in terms of their moisture equivalent.

Coated. The moisture equivalent is 2 percent or more.

Uncoated. The moisture equivalent is < 2 percent. The moisture retained at tension of 0.5 bar may be substituted for the moisture equivalent. Or, if moisture tension data are not available, the silt plus clay is ≤ 5 percent.

The moisture equivalent for this distinction is the weighted average for the control section, weighted for the thickness of each horizon or layer.

Permanent cracks.—Hydraquents consolidate[6] after drainage and become Fluvaquents. In the process, they form polyhedrons, roughly 12 to 50 cm in diameter, depending on the *n*-value and particle size. The polyhedrons are separated by cracks that range in width from 2 mm to 1 cm or more. The polyhedrons may shrink and swell with changes in moisture content of the soil, but the cracks are permanent and can persist for some hundreds of years even though the soils are cultivated. The cracks permit rapid movement of water through the soil either vertically or laterally. Yet the soils may have the same particle size, mineralogy, and other family properties as soils that are not cracked or that have cracks that open and close with the seasons. The soils that have permanent cracks are so rare in the United States that only a provisional definition of their characteristics can be presented.

The modifier "cracked" is used only to designate families of Fluvaquents. It means that there are continuous, permanent, lateral and vertical cracks, at least 2 mm wide, spaced at average lateral intervals of 50 cm or less. If this modifier is not in the family name, permanent cracks are assumed to be absent.

Families of Histosols

The order in which family modifiers are placed in the technical family names of Histosols follows. The differentiae chosen are those appropriate to the particular family.

Particle-size class
Mineralogy class, including nature of limnic deposits
Reaction class
Soil temperature class

The control section

The control section in Histosols depends on the nature of the upper part of the soil. The control section extends to any layer of water present below 130 cm or 160 cm. If a lithic or paralithic contact is present at a depth of less than 130 cm, the control section extends to the contact. The control section extends to a depth of 160 cm if (1) the upper 60 cm of the soil is three-fourths or more fibers derived from *Sphagnum* or from *Hypnum* or other mosses or if (2) the upper 60 cm has a bulk density < 0.1. If none of the aforementioned conditions is present, the control section extends to a depth of 130 cm.

Particle-size classes

Particle-size modifiers are used in family names of Histosols only in terric subgroups The terms used follow.

Fragmental
Loamy-skeletal or clayey-skeletal
Sandy or sandy-skeletal
Loamy
Clayey

The meaning of each of these terms is the same as that defined for particle-size classes of mineral soils. The proper term is selected to describe the weighted average particle size of the upper 30 cm of the mineral layer or that part of the mineral layer that is within the control section, whichever is thicker.

Mineralogy classes

Mineralogy classes of Histosols are of four kinds, based on the nature of the subgroup or great group.

Ferrihumic.—Containing ferrihumic materials within the control section (applied to Fibrists, Hemists, and Saprists, except Sphagnofibrists and sphagnic subgroups of other great groups). Bog iron is present in some Histosols or in organic soil materials. It is called ferrihumic material. It consists of authigenic deposits (formed in place) of hydrated iron oxides

[6] The process is designated by a Dutch word that means "to ripen" because the change resembles the change in consistence of cheese as water is removed.

mixed with varying kinds or amounts of organic materials. The iron in some places is present in large cemented aggregates. In other places it may be mostly dispersed and soft. Colors normally are shades of dark reddish brown, commonly mixed with black, and the colors change little on drying. The content of iron oxide ranges from 10 percent to > 20 percent.

Ferrihumic material either is saturated with water for long periods (>6 months) or is in an artificially drained soil. The content of free iron oxide should exceed 10 percent (7 percent Fe), but the horizon may be either organic or mineral provided there is at least 1 percent organic matter. The material should have > 2 percent (by weight) concretions of iron, which may range in size from fine (<5 mm) to 1 m or more in the largest lateral dimension. Colors should be dark reddish brown or reddish brown or should be close to these colors. The presence of ferrihumic material within the control section is one of the family differentiae.

If ferrihumic is used as a modifier in the technical family name, no other mineralogy modifier is used because the presence of the iron is considered to be, by far, the most important characteristic.

Modifiers applied only to terric subgroups.—The mineralogy modifiers used for mineral soils are applied to the mineral parts of the soil for which a particle-size modifier has been used if the mineralogy is not ferrihumic.

Clastic.—More than 55 percent mineral matter (total ash after ignition) as a weighted average of the organic materials within the control section (applied to all subgroups, except hydric and terric, that do not have ferrihumic mineralogy).

Modifiers applied to limnic subgroups.—If limnic materials are present in the control section, if they are 5 cm or more thick, and if the materials do not have ferrihumic mineralogy, the following modifiers are used.

Coprogenous. Limnic materials that consist of coprogenous earth are present.

Diatomaceous. Limnic materials that consist of diatomaceous earth are present.

Marly. Limnic materials that consist of marl are present.

Reaction classes

Modifiers to indicate reaction are used in all subgroups. The meanings follow.

Euic.—The pH of undried samples is 4.5 or more (0.01 M $CaCl_2$) in at least some part of the organic materials in the control section.

Dysic.—The pH is <4.5 (in 0.01 M $CaCl_2$) in all parts of the organic materials in the control section.

Soil temperature classes

Names and definitions of classes follow the rules given for soil temperature classes of mineral soils. Frigid, however, is redundant in boric and cryic great groups and is not used. No temperature modifier is used in pergelic subgroups.

Soil depth classes

Soil depth modifiers are used in all lithic subgroups of Histosols except in the suborder of Folists. It is assumed that lithic Folists have a shallow lithic contact. Other lithic Histosols have a lithic contact within the control section but it may be as much as 160 cm deep.

Shallow.—Used in lithic subgroups to indicate a lithic contact between a depth of 18 cm and 50 cm.

Micro.—Used to indicate a lithic contact shallower that 18 cm without regard to soil temperature. (In mineral soils, micro families are restricted to cryic great groups.)

Geology - Stateline Planning Unit (0504)

The oldest rocks found in the planning unit are a Pre-Cambrian (older than 600 million years) metamorphic complex that occurs in the southeastern portion of the unit.

These rocks were changed by heat and pressure, from interbedded shales and sandstones that were originally deposited in shallow seas, into a complex of mica shists, chlorite schists and quartzose gneisses. These recrystallized rocks were intruded several times by igneous (molten) rocks. Most of these intrusive rocks are also of Pre-Cambrian age. Most of these igneous rocks are granitic in composition but aplites, pegmatites and amphibolities also occur as small dikes.

The metamorphic-igneous complex of rocks is the predominant material composing the Opal, Newberry, Lucy Grey and southern McCullough Mountains (see figure #3).

These rocks were originally deposited as sandstones and shales in a shallow sea that covered the area during parts of the Pre-Cambrian era. These sediments were derived by erosion from even older mountains. During this period of time, volcanos were also active in the area and lavas were also deposited. Subsequent erosion and deposition of new sediments buried these older sediments and lavas and the pressure and heat of this deep burial transformed them into the metamorphic rocks now exposed in the planning unit.

These deeply buried and recrystallized rocks were uplifted and exposed to weathering and erosion more than 600 million years ago. At the beginning of the Paleozoic (Ancient Life) era about 600 million years ago, the area was flooded by another incursion of the ocean. New sediments, many with abundant fossils, were deposited in this sea. The first of these sediments were sandstones but with time finer sediments such as shales and finally limestones were formed. The presence of limestone along with corals and other warm water animals, indicates that during this period, the climate of southern Nevada was similar to

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that of the present day Bahamas. This warm inland sea persisted for about 350 million years, but became smaller and more restricted as time passed. The open seas were replaced by coal swamps over much of the continent, and these swamps were replaced eventually by dry uplands. As the sea retreated, the climate of the continent became drier especially in the continental interior. By the end of the Paleozoic much of the North American continent was dry land and large portions had arid or semi-arid climates. Red sandstones, which are thought to represent ancient sand dunes that have been preserved into the present time, were formed. These changes, which are thought to be the result of the formation of a super-continent by the collision and joining of smaller land masses, caused the extinction of many plants and animals that had prospered in the early Paleozoic (1).

Rocks of Paleozoic age occur throughout the Stateline Planning Unit and make up a great portion of the mountains within and around the unit. They comprise, for example, the majority of the rocks found in the Spring Mountains. Rocks of this age are shown in blue on figures #3 and #4. They also occur in the Bird Spring and Sunrise Mountains.

Arid conditions and subaerial deposition of sediments persisted well into the Mesozoic Era. Red cross-bedded sandstones, such as the Aztec Formation, and thick gypsum deposits, both of which are indicators of desert climates, were formed during this period of time. Rocks of this age are best exposed in the Red Rock Canyon Recreation Lands which are within the Stateline Planning Unit and also in the Valley of Fire State Park which is within the Virgin Valley Planning Unit (0502). Rocks of this type are shown in purple in figures #3 and #4.

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The Mesozoic (Middle Life) Era during which these red sandstones were formed is known as the Age of Dinosaurs. For the 125 million years that the Mesozoic Era covers, dinosaurs were the highest and most advanced forms of life on earth. The small animals which would eventually give rise to the mammals and man did not appear until late in the Mesozoic. It was also during this era that the first flowering plants appeared. These new plants began to replace the older non-flowering plants such as ferns, conifers, etc., which though they have persisted into the present no longer make up the bulk of the plants of the world.

The Mesozoic Era closed about 60 million years ago and was marked by another great extinction. Many animals and plants, and all of the dinosaurs, which had flourished for so long passed from the face of the earth.

The Cenozoic (Recent Life) Era which followed the Mesozoic was a time of great activity for the small mammals that had lived in the shadows of the dinosaurs. They and the flowering plants, having survived the extinctions at the end of the Mesozoic, evolved rapidly and many of the plants and animals familiar to us today began to appear. The grasses, however, did not appear until the middle of the period.

This period was also a time of great tectonic activity in the western United States. This activity began in the Mesozoic but culminated in the Cenozoic. Earthquakes and volcanos were common and large masses of lava were poured out onto the land. Lavas of this age occur throughout the planning unit and are shown on figures #3 and #4 in red. The River, Eldorado, Highland Springs and MuCullough Mountains are composed rocks of this type.

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All of this activity seems to be the result of the North American continent overriding the Pacific Ocean's bottom (1). The resulting stress of the rocks grinding over and under each other caused the land surface to buckle and crack. These cracks took three forms. One, known as block faulting caused the down-dropping blocks formed of land relative to other blocks. These down-dropping blocks formed the valleys of the Basin and Range Province while the uplifted blocks formed the mountains. Erosion of these mountains brought sediments into the valleys which began to fill. Figure #5 shows the main block faults of Nevada.

The second type of faulting is thrust faulting. In this type, blocks of rock are pushed over other blocks. In most of the faults of this type, that occur in southern Nevada, the rocks were pushed from the west and over-rode rocks to the east (see figure #6).

The third type of faulting that occurred is strike-slip or lateral faulting. In this type of faulting, blocks of rock slide past each other without a great deal of up or down motion. The best known example of this type of fault is the San Andreas fault in California. It is this fault and its satellites that cause the earthquake damage in that state. The fault that underlies the Las Vegas Valley (see figures #5, #6, #7, and #8) is this type of fault. Indeed, it may be an old, inactive, portion of the San Adreas fault system (8).

All of this tectonic activity slowly came to an end, at least in southern Nevada, toward the end of the Cenozoic. The only earthquake activity of note in the Stateline Planning Unit area has been caused

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by man. Earthquakes were noted around the Hoover Dam area as the water behind the dam began to deepen to form Lake Mead (4). Such earthquakes are the result of the underlying rocks adjusting themselves to the added load on them due to the water (4). Small tremblors have also been felt in the area during atomic bomb tests at the test site.

About one million years ago, the world entered the Ice Age. During this time, when much of the northern hemisphere was covered by glacial ice, southern Nevada had a wetter climate than it does at present. Many of the now dry lakes and rivers contained water for long periods of time. Trees such as ash and juniper, which are now restricted to the mountains, grew on the Las Vegas Valley floor (9). Large mammals such as camels, ancient horses, and mammoths, now all extinct, roamed the valleys (9). About 12,000 years ago the Ice Age ended and southern Nevada began to dry out and become the desert we have today. At about the same time man first appeared in the area and left artifacts near Tule Springs (9).

Minerals and Mining

The Stateline Planning Unit is part of the Eastern Nevada Metallogenic Province (see figure #9). This province is characterized by major lead and zinc deposits with associated gold and silver. The western province has the major gold, silver, tungsten, antimony, mercury, and iron deposits so far discovered.

Within these provinces, metallic minerals are not randomly distributed but occur along specific belts or trends which cross the state (see figure #10). Most of these mineral belts trend NW-SE but a few trend E-W or even NE-SW. No such mineral belt is reported in the

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Stateline Planning Unit, but the locations of the major metallic mineral deposits do seem to follow a trend (see figure #11). Beginning at the Potosi lead-silver mine, a NW-SE trend leads through Goodsprings, Sunset, Crescent, Searchlight, and Newberry. Nelson could also be included in such a trend. Most of these deposits are associated with igneous rocks that have intruded Pre-Cambrian or Paleozoic rocks.

Non-metallic minerals such as gypsum, clay, sand and gravel, and so on, are more widespread and do not exhibit any special trends. They are associated with a variety of sedimentary rock types. Most such deposits are Mesozoic or younger in age.

The individual mining areas and mineral deposits will be discussed in the Mineral Resource Analysis of the Stateline Planning Unit.

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References

Calder, N., 1972. The Restless Earth - a report on the New Geology: Viking Press, N.Y., 152p.

Coffman, J.L., and C.A. von Hake, 1972, United States Earthquakes, 1970: Nat. Oceanic and Atmospheric Admin., Bull. 1-TS6937, 81p.

Cornwall, H.R., 1972, Geology and Mineral Deposits of Southern Nye County, Nevada: Nev. Bur. of Mines, Bull. 77, 49p.

Corps of Engineers, 1967, Flood Plain Information - Lower Las Vegas Wash, Clark County, Nevada: 23p.

Fuhriman and Barton, 1971, Ground Water Pollution in Arizona, California, Nevada and Utah: E.P.A., Water Pollution Control Research Studies, 16060 ERV, 249p.

Joint Panel on Problems Concerning Seismology and Rock Mechanics, 1972, Earthquakes related to reservoir filling: Nat. Tech. Info. Serv., PB-208327, 24p.

Leopold, Wolman, and Miller, 1964, Fluvial Processes in Geomorphology: W.H. Freeman and Co., 522p.

Longwell, et al, 1965, Geology and Mineral Deposits of Clark County, Nevada: Nev. Bur. of Mines, Bull. 62, 218p.

McHarg, I.L., 1969, Design with Nature: Doubleday and Co., Inc., 197p.

Mindling, A., 1971, A Summary of Data Relating to Land Subsidence in Las Vegas Valley: Desert Research Institute, Reno, Nev., 55p.

Pacific Southwest Inter-Agency Committee for the United States Water Resources Council, 1971, The Pacific Southwest Analytical Summary Report on Water and Land Resources: Water Resources Council publication, 185p.

Spencer, E.W., 1962, Basic Concepts of Historical Geology: T.Y. Crowell Co., N.Y., 499p.

U.S.G.S. and Nev. Bur. of Mines, 1964, Mineral and Water Resources of Nev.: Nev. Bur. of Mines, Bull. 65, 314p.

Water Resources Council, 1969, Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies: Water Resources Council, 45p.

Water Resources Council, 1971, Regulation of Flood Hazard Areas to Reduce Flood Losses, Vol. 1, parts I-IV: Water Resources Council, 578p.

Wormington and Ellis (eds.), 1967, Pleistocene Studies in Southern Nevada: Nev. State Museum, Anthro. Papers #13, 411p.

Robert J. Sulenski
May 30, 1973

References

Calder, N., 1972. The Restless Earth - a report on the New Geology: Viking Press, N.Y., 152p.

Coffman, J.L., and C.A. von Hake, 1972, United States Earthquakes, 1970: Nat. Oceanic and Atmospheric Admin., Publ. I-TS6937, 81p.

Cornwall, H.R., 1972, Geology and Mineral Deposits of Southern Nye County, Nevada: Nev. Bur. of Mines, Bull. 77, 49p.

Corps of Engineers, 1967, Flood Plain Information - Lower Las Vegas Wash, Clark County, Nevada: 23p.

Fuhriman and Barton, 1971, Ground Water Pollution in Arizona, California, Nevada and Utah: E.P.A., Water Pollution Control Research Studies, 16060 EKV, 249p.

Joint Panel on Problems Concerning Seismology and Rock Mechanics, 1972, Earthquakes related to reservoir filling: Nat. Tech. Info. Serv., PB-208327, 24p..

Leopold, Wolman, and Miller, 1964, Fluvial Processes in Geomorphology: W.H. Freeman and Co., 522p.

Longwell, et al, 1965, Geology and Mineral Deposits of Clark County, Nevada: Nev. Bur. of Mines, Bull. 62, 218p.

McHarg, I.L., 1969, Design with Nature: Doubleday and Co., Inc., 197p.

Mindling, A., 1971, A Summary of Data Relating to Land Subsidence in Las Vegas Valley: Desert Research Institute, Reno, Nev., 55p.

Pacific Southwest Inter-Agency Committee for the United States Water Resources Council, 1971, The Pacific Southwest Analytical Summary Report on Water and Land Resources: Water Resources Council publication, 185p.

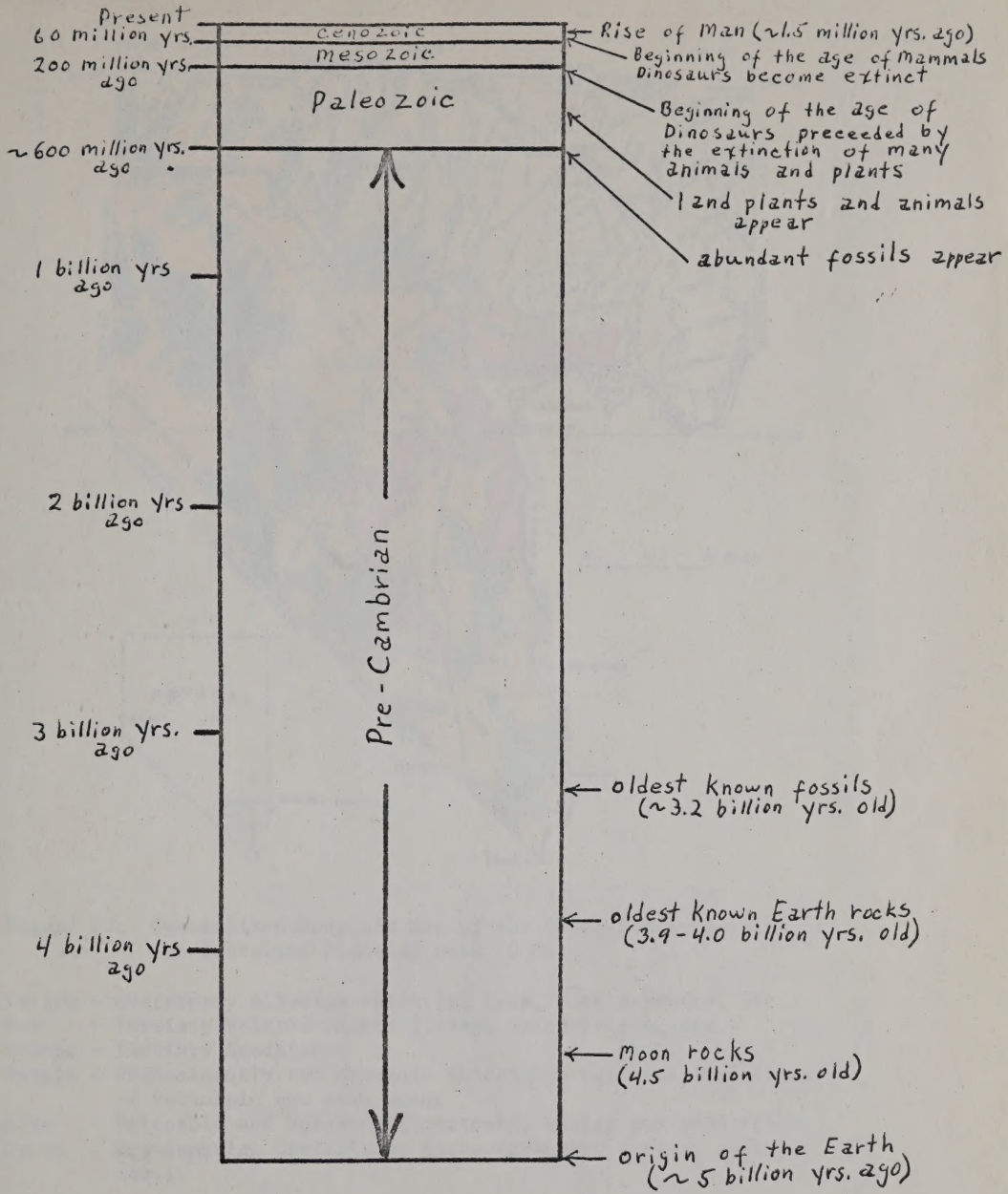
Spencer, E.W., 1962, Basic Concepts of Historical Geology: T.Y. Crowell Co., N.Y., 499p.

U.S.G.S. and Nev. Bur. of Mines, 1964, Mineral and Water Resources of Nev.: Nev. Bur. of Mines, Bull. 65, 314p.

Water Resources Council, 1969, Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies: Water Resources Council, 45p.

Water Resources Council, 1971, Regulation of Flood Hazard Areas to Reduce Flood Losses, Vol. I, parts I-IV: Water Resources Council, 578p.

Wormington and Ellis (eds.), 1967, Pleistocene Studies in Southern Nevada: Nev. State Museum, Anthro. Papers #13, 411p.


Present
60 million yrs.
200 million yrs. ago
~600 million yrs. ago
1 billion yrs ago
2 billion yrs ago
3 billion yrs. ago
4 billion yrs ago
Cenozoic
Mesozoic
Paleozoic
Pre-Cambrian
Rise of Man (~1.5 million yrs. ago)
Beginning of the age of mammals
Dinosaurs become extinct
Beginning of the age of Dinosaurs preceeded by the extinction of many animals and plants
1zad plants and animals appear
abundant fossils appear
oldest known fossils (~3.2 billion yrs. old)
oldest known Earth rocks (3.9-4.0 billion yrs. old)
Moon rocks (4.5 billion yrs. old)
origin of the Earth (~5 billion yrs. ago)

Geologic Time Scale

(from: Calder, 1972, and Spencer, 1962)

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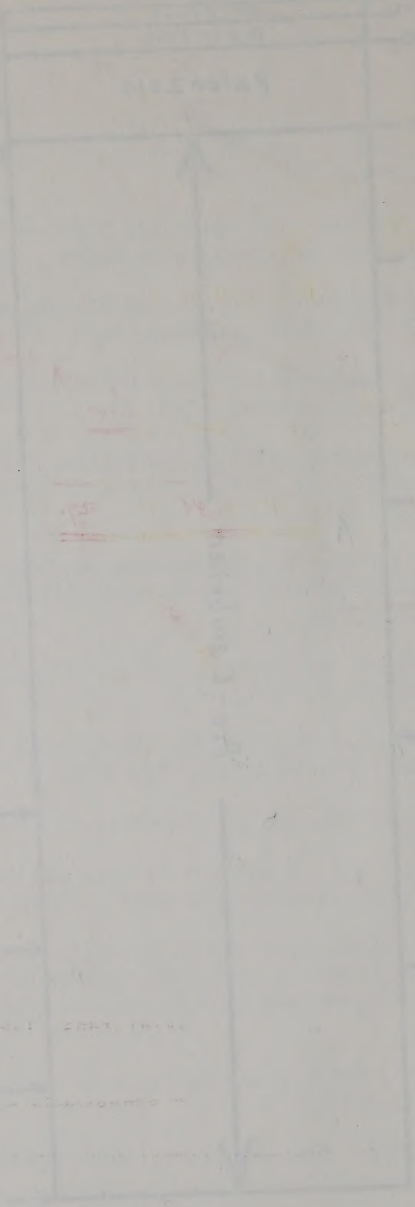
January 15, 1973



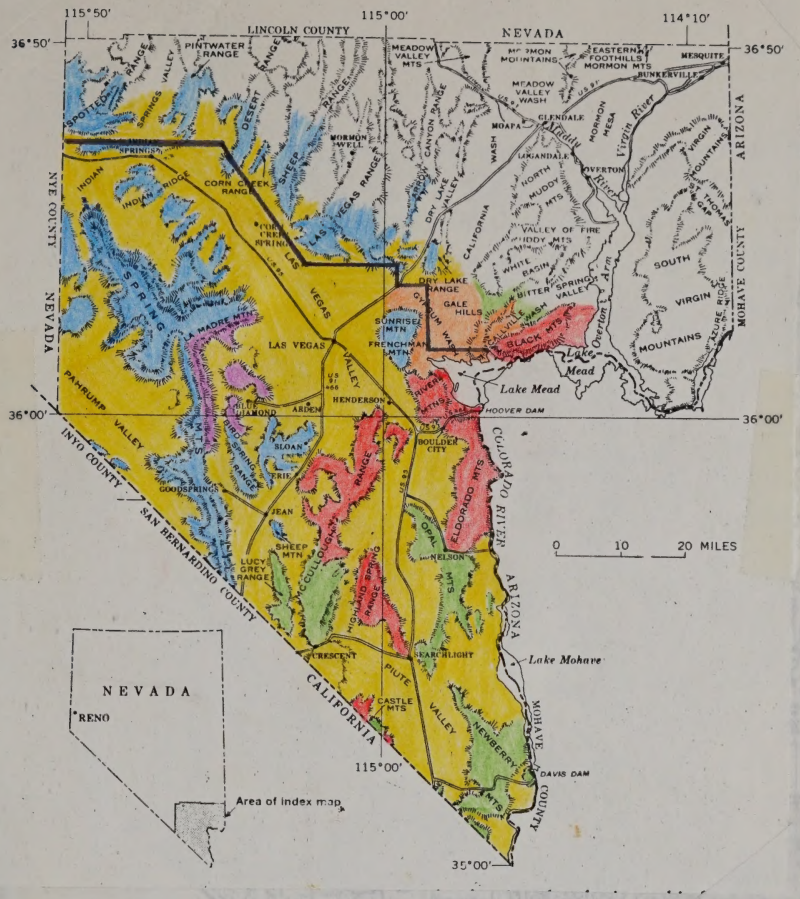


Figure #3: Generalized Geologic Map of the Clark County portion of the Stateline Planning Unit (0504).

Yellow - Quaternary Alluvium (alluvial fans, lake deposits, etc.)
Red - Tertiary Volcanic Rocks (lavas, volcanic ash, etc.)
Orange - Tertiary Sandstones
Purple - Predominantly red Mesozoic sandstones but some limestones of Paleozoic age also occur
Blue - Paleozoic and Mesozoic limestones, shales and sandstones
Green - Pre-Cambrian Crystalline Rocks (granite, gneiss, schist, etc.)

(From Longwell et al, 1965, Geology and Mineral Deposits of Clark County, Nevada.)

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Figure #3: Generalized Geologic Map of the Clark County portion of the Stateline Planning Unit (050A).

Yellow - Quaternary Alluvium (alluvial fans, lake deposits, etc.)
Red - Tertiary Volcanic Rocks (lavas, volcanic ash, etc.)
Orange - Tertiary Sandstones
Purple - Predominantly red Mesozoic sandstones but some limestones of Paleozoic age also occur
Blue - Paleozoic and Mesozoic limestones, shales and sandstones
Green - Pre-Cambrian Crystalline Rocks (granite, gneiss, schist, etc.)

(From Longwell et al, 1965, Geology and Mineral Deposits of Clark County, Nevada.)

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Figure #4: Generalized Geologic Map of the Nye County portion of the Stateline Planning Unit (0504)

Yellow - Quaternary Alluvium (alluvial fans, lake sediments, etc.)
Red - Tertiary Volcanic Rocks (lavas, volcanic ash, etc.)
Blue - Paleozoic and Mesozoic Rocks (predominantly limestone but some sandstone & shale also occurs)

(From Cornwall, 1972, Geology and Mineral Deposits of Southern Nye County, Nevada.)

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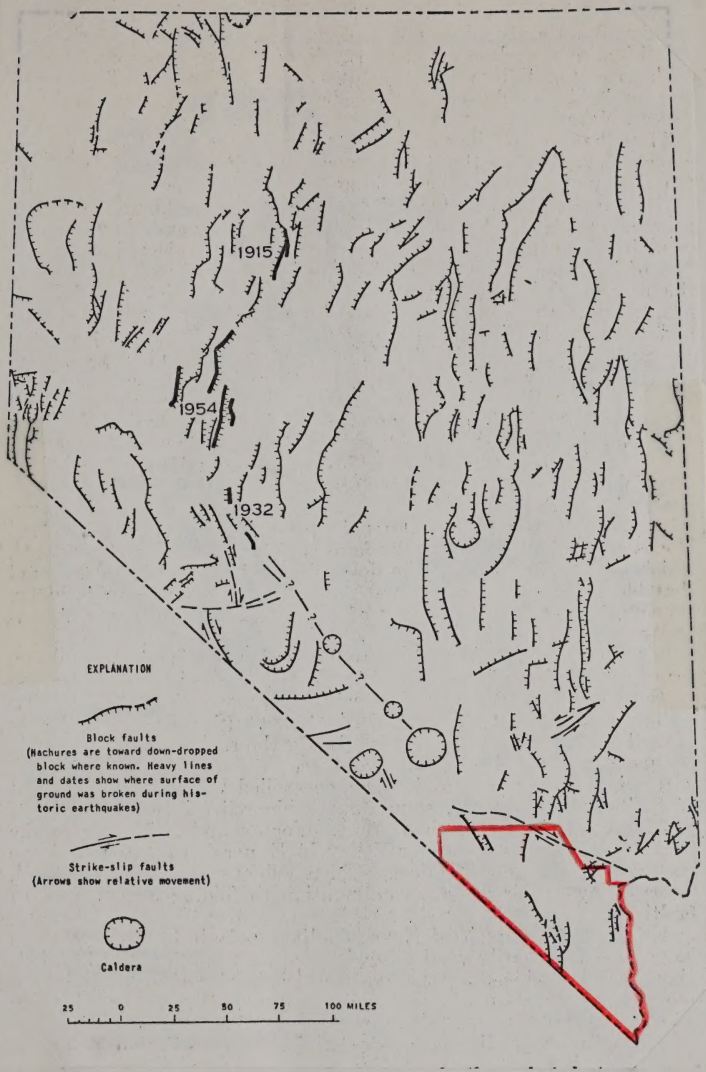
1915
1954
1932
EXPLANATION
Block faults
(Hachures are toward down-dropped block where known. Heavy lines and dates show where surface of ground was broken during historic earthquakes)
Strike-slip faults
(Arrows show relative movement)
Caldera
25 0 25 50 75 100 MILES

Figure #5: The Stateline Planning Unit (0504) in relation to the major Basin and Range block faults of Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

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January 15, 1973

Figure 96: The Stateline Planning Unit (050A) in relation to the major thrust faults (exclusive of the Roberts Mountains fault) and strike-slip faults of Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

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January 15, 1973

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January 15, 1973

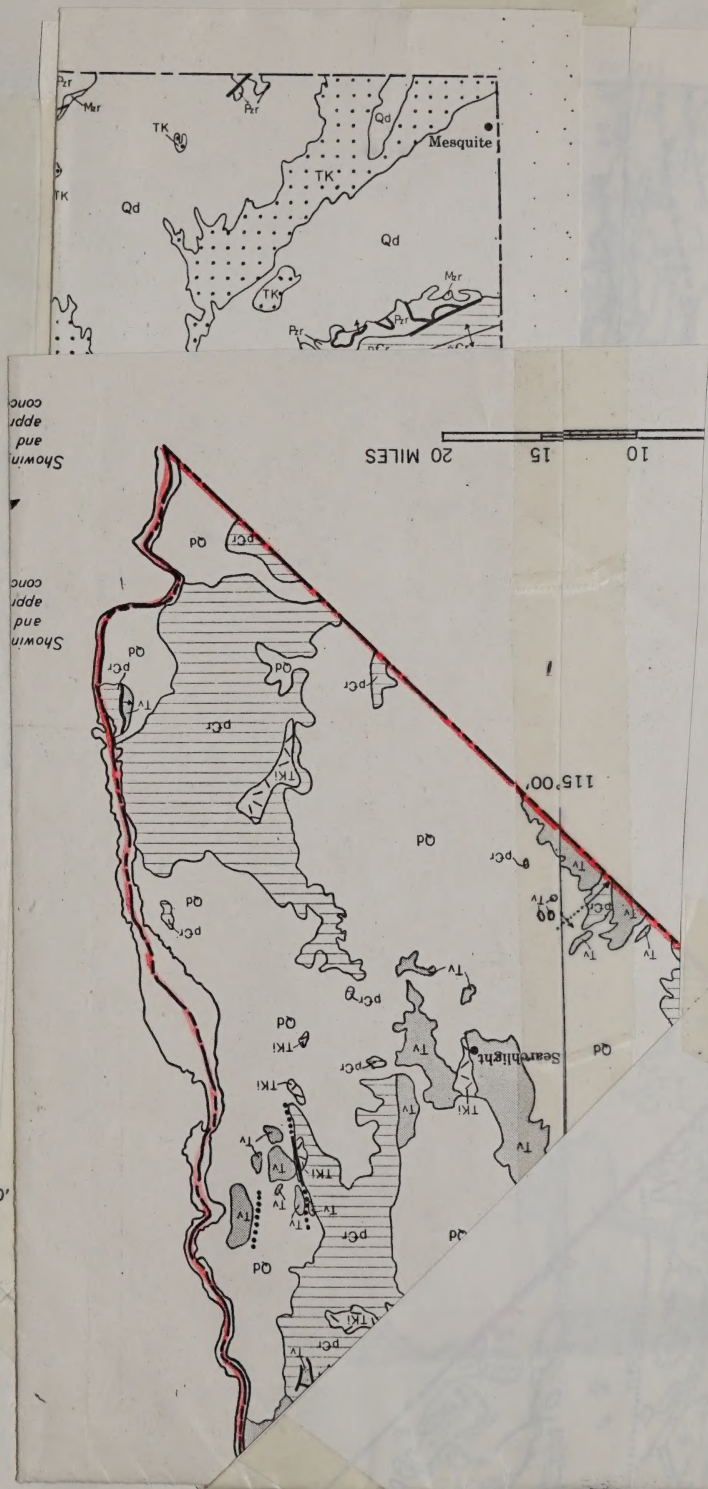

Figure #7: Major Structural Features in Clark County. The Clark County portion of the Stateline Planning Unit (0504) is outlined in red. (From Longwell et al, 1965, Geology and Mineral Deposits of Clark County, Nevada.)

Figure #6: The Stateline Planning Unit (050A) in relation to the major thrust faults (exclusive of the Roberts Mountains fault) and strike-slip faults of Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

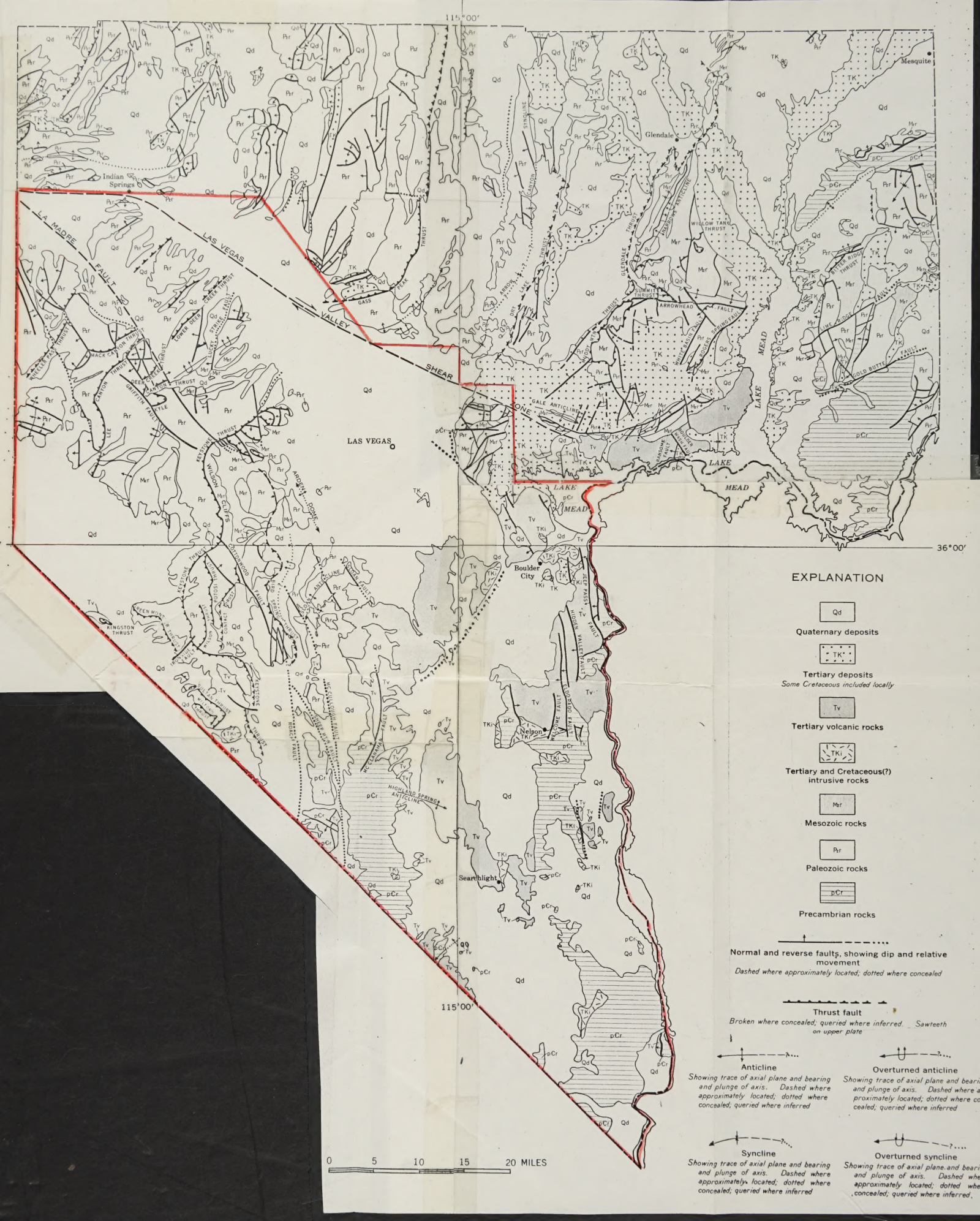
115°00′
36°00′
Mesquite
Glendale
Indian Springs
LAS VEGAS
Boulder City
Nelson
Searchlight
LA MADRE FAULT
LAS VEGAS VALLEY SHEAR ZONE
LAKE MEAD
KINGSTON THRUST
0 5 10 15 20 MILES
EXPLANATION
Qd
Quaternary deposits
TK
Tertiary deposits
Some Cretaceous included locally
Tv
Tertiary volcanic rocks
TKi
Tertiary and Cretaceous(?) intrusive rocks
Mzr
Mesozoic rocks
Pzr
Paleozoic rocks
pCr
Precambrian rocks
Normal and reverse faults, showing dip and relative movement
Dashed where approximately located; dotted where concealed
Thrust fault
Broken where concealed; queried where inferred. Sawteeth on upper plate
Anticline
Showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located; dotted where concealed; queried where inferred
Overturned anticline
Showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located; dotted where concealed; queried where inferred
Syncline
Showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located; dotted where concealed; queried where inferred
Overturned syncline
Showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located; dotted where concealed; queried where inferred.

Figure #8: Major Structural Features in Southern Nye County. The Nye County portion of the Stateline Planning Unit (0504) is outlined in red. (From Cornwall, 1972, Geology and Mineral Deposits of Southern Nye County, Nevada.)

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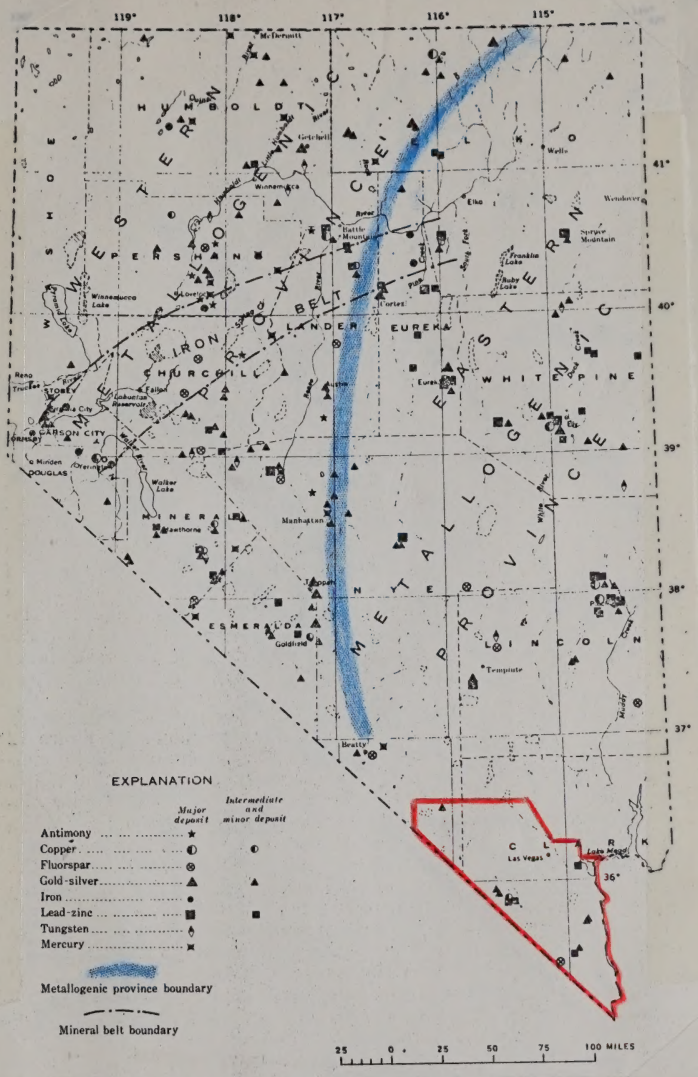

Figure #9: The Stateline Planning Unit (0504) in relation to the metallogenic provinces and major mineral deposits in Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

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January 15, 1973

Figure 59: The Sierrelina Planning Unit (0504) in relation to the metallogenic provinces and major mineral deposits in Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

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January 15, 1973

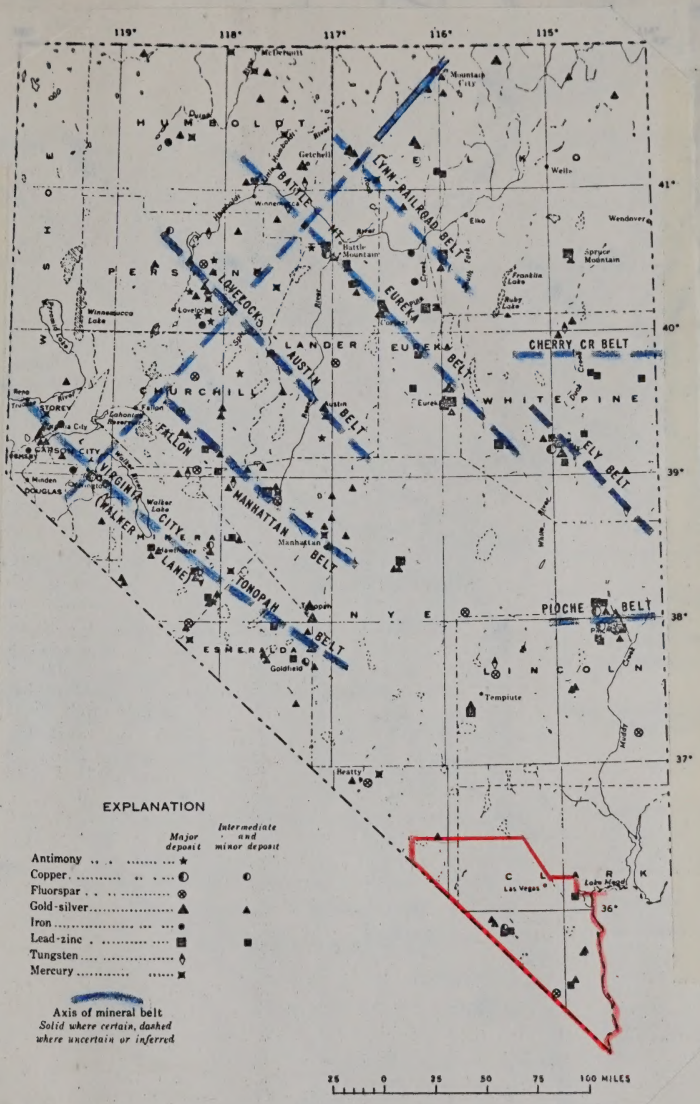

Figure #10: Stateline Planning Unit (0504) in relation to the Mineral Belts and Major Deposits of Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

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January 15, 1973

Figure #10: Statewide Planning Unit (050A) in relation to the Mineral Belts and Major Deposits of Nevada. The Planning Unit is outlined in red. (From U.S.G.S., 1964, Mineral and Water Resources of Nevada.)

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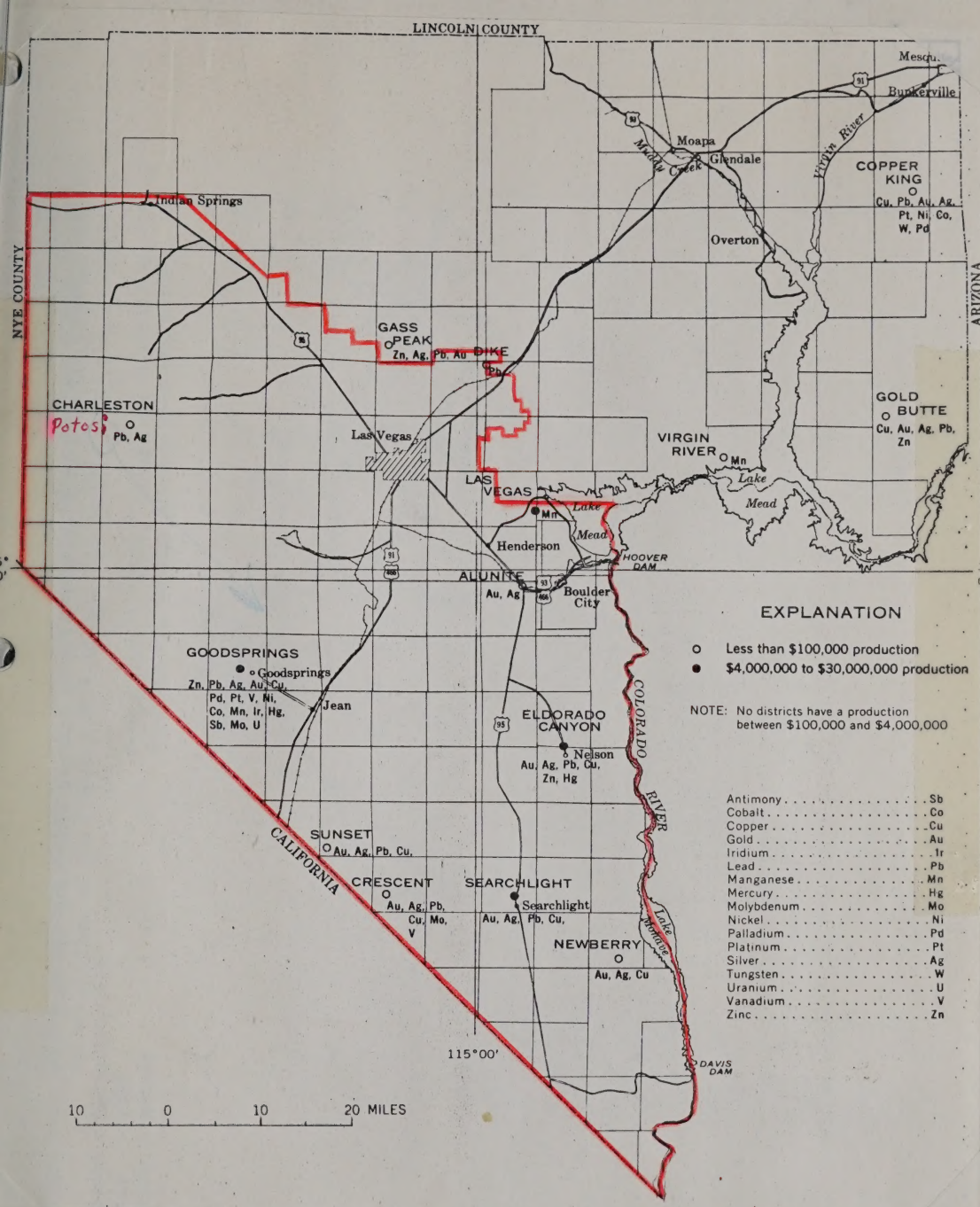

Figure #11: Metal Mining in the Clark County portion of the Stateline Planning Unit (0504). The Clark County portion of the Planning Unit is outlined in red. (From Longwell et al, 1965, Geology and Mineral Deposits of Clark County, Nevada.)

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January 15, 1973

Figure #11: Metal Mining in the Clark County portion of the Stateline Planning Unit (0504). The Clark County portion of the Planning Unit is outlined in red. (From Longwell et al.

Figure #12: Mining in the Nye County portion of the Stateline Planning Unit (0504). The Nye County portion of the Planning Unit is outlined in red.

Purple - bentonite clay
Blue - gold
Green - silver

(From Cornwall, 1972, Geology and Mineral Deposits of Southern Nye County, Nevada, plus additions.)

Physical Hazards
Stateline-Virgin Valley Resource Areas

A. Natural Hazards:

1. Earthquakes:

As noted in the geology section of the Physical Profile, southernmost Nevada is relatively stable geologically. Both thrust and normal faults are common in the area, but these faults have been inactive for long periods of time. No damaging earthquakes have been reported in the area from earliest history through 1971. Earthquakes that moved heavy furniture or caused some falling plaster (intensity VI) may have occurred but have not been reported. Certainly no earthquakes causing more than slight to moderate damage (intensity VII) have ever been reported (see map #1 and 2).

The area from Esmeralda County west to the Reno-Carson City area is moderately active in a geologic sense and numerous small earthquakes, usually less than intensity 3 and rarely more than intensity 4.5 have occurred. The Nevada Bureau of Mines has been monitoring these shocks for some years. Map #3 summarizes their findings for the period between April 1, 1970 and December 31, 1971. During or just prior to the period, two earthquakes of intensity IV occurred which might have been felt in other areas. These shocks would have produced effects at their epicenters similar to that of a truck hitting a building. Away from the epicenters the effects would be restricted to dish-rattling and wall creaking (Coffman & Van Hahe, 1972).

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Physical Hazards
Stateline-Virgin Valley Resource Areas

A. Natural Hazards:

1. Earthquakes:

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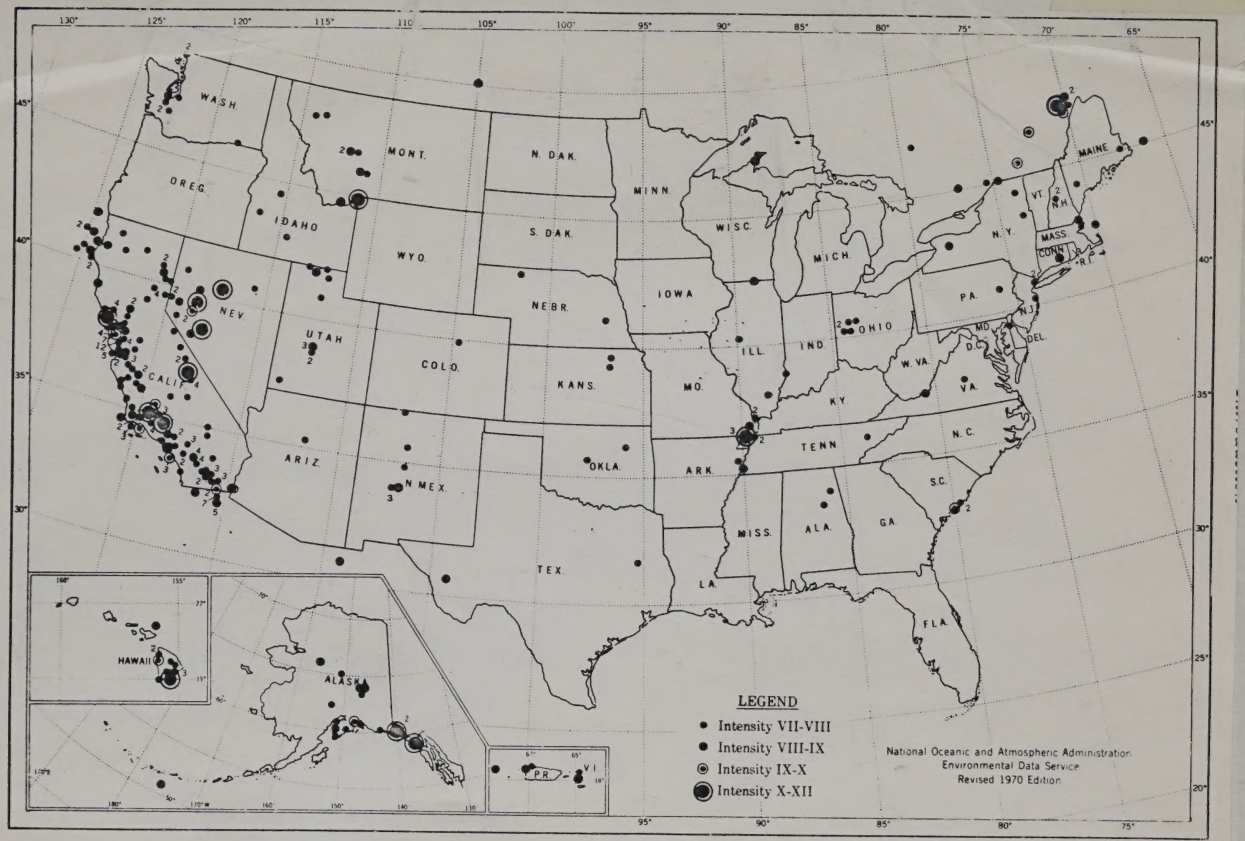

FIGURE 1.—Damaging earthquakes in the United States from earliest history through 1970.

Map #1 (from Coffman & Von Hake, 1972)

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9/11/73

Wash #1 (Plus cotton & Any Hard Water)

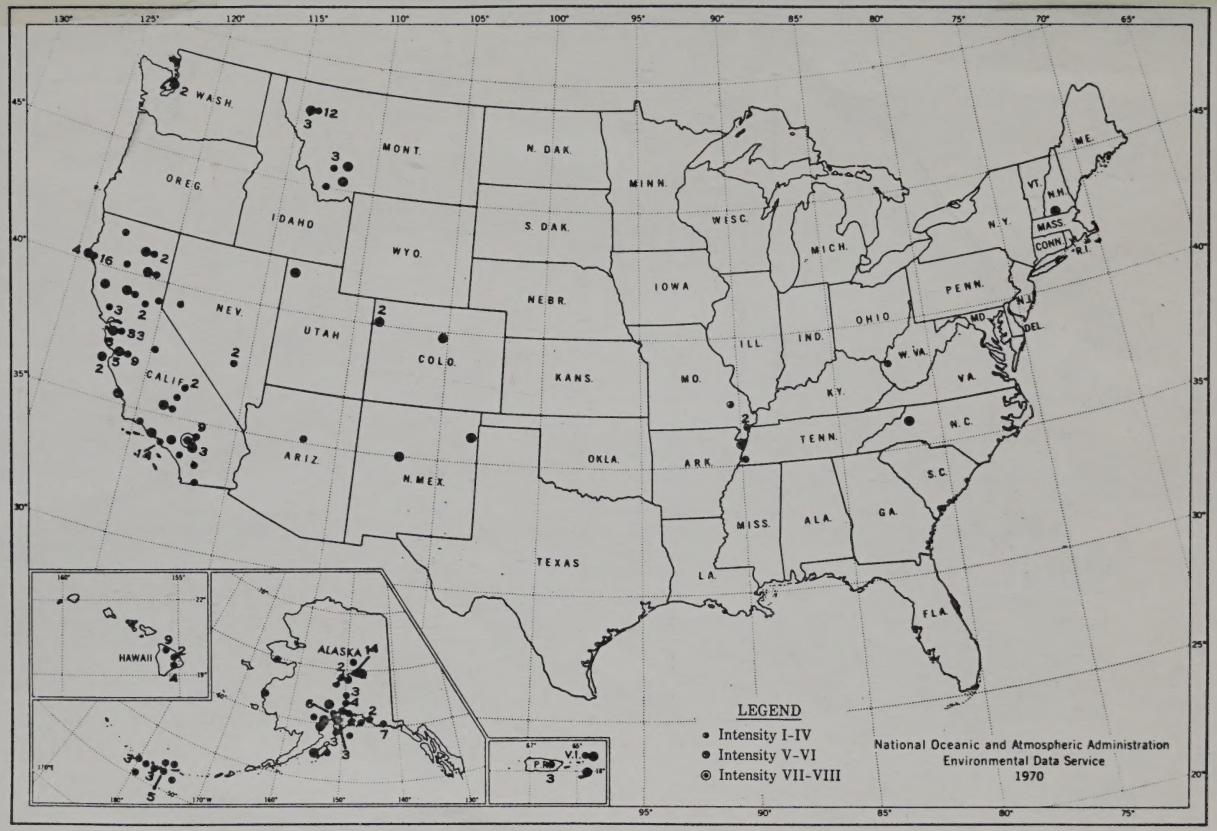

FIGURE 2.—Locations of earthquakes that were felt or caused damage in the United States during 1970.

Map #2 (from Coffman + Von Hake, 1972)

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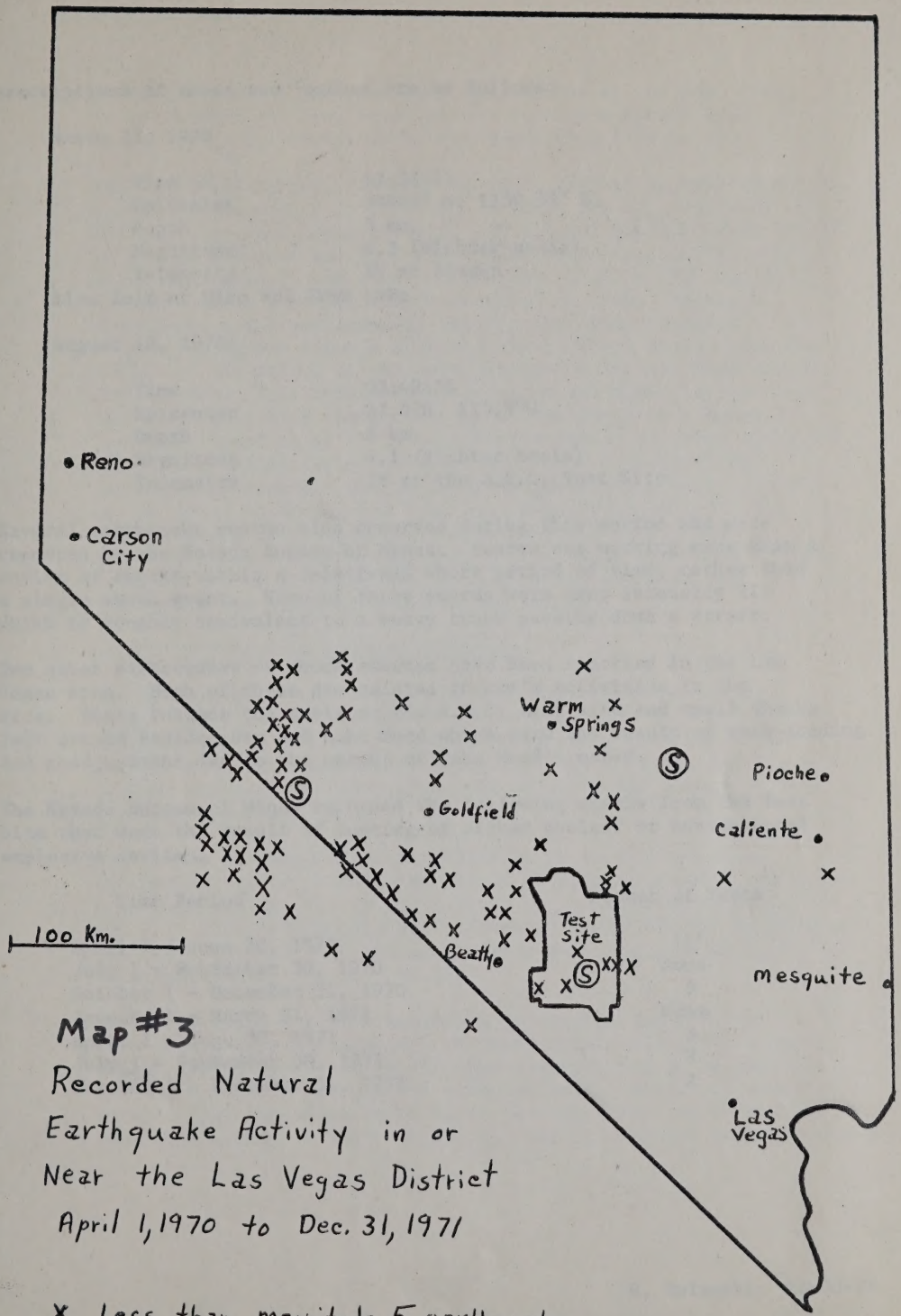

Map #3

Recorded Natural Earthquake Activity in or Near the Las Vegas District
April 1, 1970 to Dec. 31, 1971

× Less than magnitude 5 earthquake
Ⓢ Earthquake swarm

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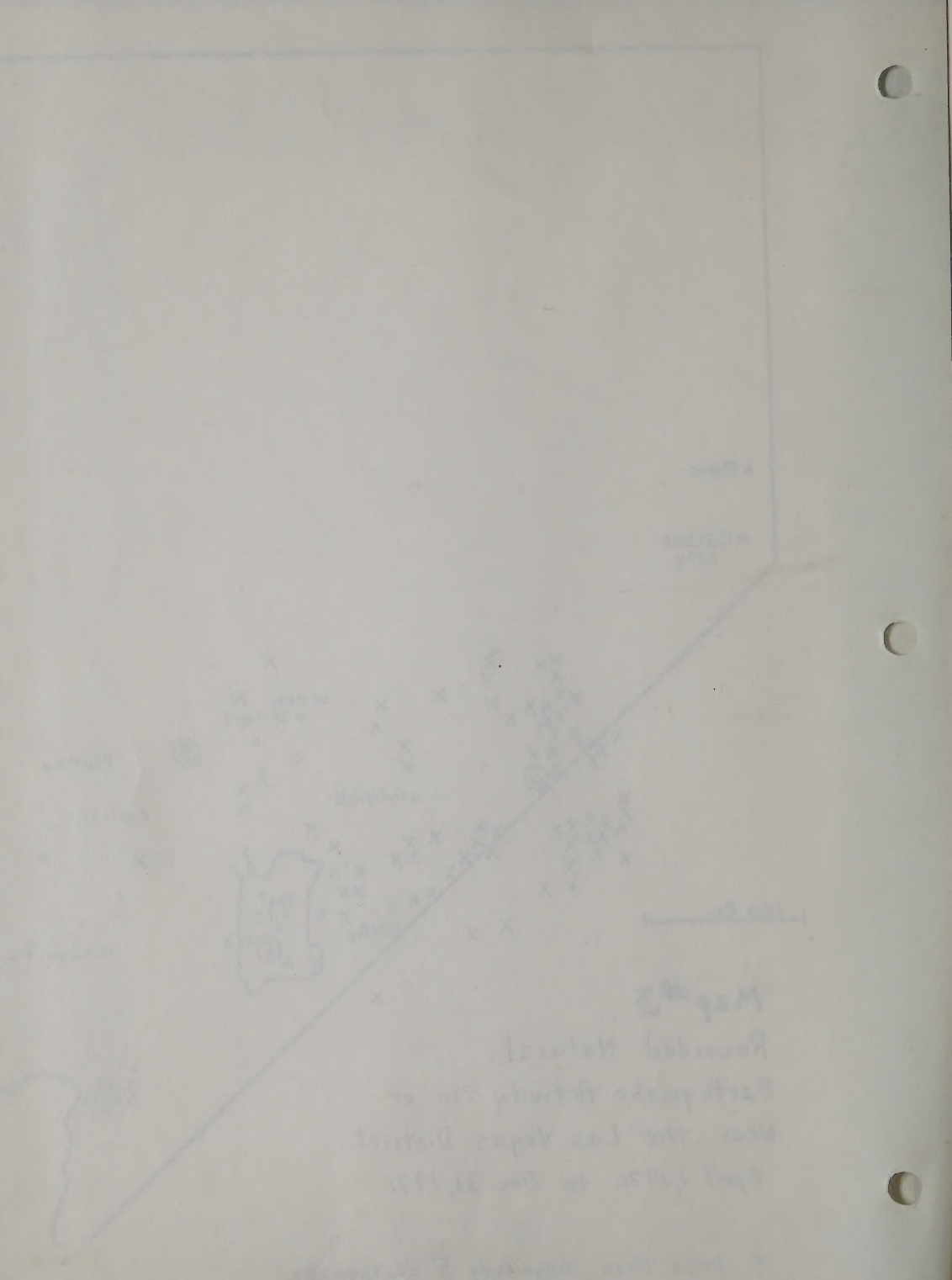

Descriptions of these two 'quakes are as follows:

March 23, 1970

Time	12:52:12
Epicenter	37°45' N, 115° 59' W.
Depth	5 km.
Magnitude	4.2 (Richter scale)
Intensity	IV at Adaven

Also felt at Hiko and Grim Lake

August 10, 1970

Time	03:48:56
Epicenter	37.2°N, 115.9°W
Depth	3 km.
Magnitude	4.1 (Richter scale)
Intensity	IV at the A.E.C. Test Site

Several earthquake swarms also occurred during this period and were reported by the Nevada Bureau of Mines. Swarms are nothing more than a series of shocks within a relatively short period of time, rather than a single shock event. None of these swarms were over intensity III which is roughly equivalent to a heavy truck passing down a street.

Two other earthquakes or shock sources have been reported in the Las Vegas area. Both of these are related to man's activities in the area. These include the tests at the A.E.C. test site and small shocks felt around Boulder Dam and Lake Mead which were the result of rock-loading and readjustment due to the weight of Lake Mead's water.

The Nevada Bureau of Mines recorded the following shocks from the Test Site that were the result of testing of either nuclear or conventional explosive devices.

Time Period	Number of Tests
April 1 - June 30, 1970	11
July 1 - September 30, 1970	None
October 1 - December 31, 1970	5
January 1 - March 31, 1971	None
April 1 - June 30, 1971	3
July 1 - September 30, 1971	3
October 1 - December 31, 1971	2

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Epicenter	37°45' N, 115° 59' W.
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R. Sulenski,-9-13-73 3

While these tests may have been spectacular at the Test Site, it is doubtful if they were felt or noticed anywhere else except by sophisticated machinery monitoring such tests.

The Lake Mead earthquakes have become a classic example of earthquakes due to reservoir filling. Boulder Dam was completed in 1935 and the lake began to fill. It reached maximum water level in 1941. The area had been considered as seismically inactive up to that point. The first shocks were felt in 1936 and the greatest shock (magnitude 5.0) occurred in 1939. Although shocks are still occasionally felt in the area, the main activity occurred between 1936 and 1947. These shocks were the result of the weight of the water impounded in Lake Mead behind Boulder Dam. This extra weight stressed the rocks in the area and they readjusted themselves to the new level by a general land subsidence of up to 12 centimeters and by movement along the many minor faults in the area. These fault movements were felt as earthquakes. Though numerous shocks have been recorded in the area, no damage has ever been reported. As indicated, the situation appears to have stabilized and shocks are becoming rarer. Map #4 indicates the location and number of the recorded shocks in this area as well as the measured land subsidence due to the loading of the rocks.

2. Land Subsidence and Related Phenomena:

Two instances of land subsidence have been reported in the area. The first has already been mentioned and is the result of rock-loading by the water of Lake Mead. This subsidence took place during and immediately after the lake filling, and has not changed appreciably since then. Map #4 shows the extent of this land subsidence.

The second instance of land subsidence is in the Las Vegas Metropolitan area, and is the result of aquifer-pumping and sediment compression. It is still going on and will continue to do so until the over-pumping and depletion of the aquifer is stopped. Maps #5 through 8 show the progression and extension of this subsidence area from 1935 to 1963.

Land subsidence has been occurring in the Las Vegas Valley area apparently for thousands of years mainly along the scarps which will be discussed later. The over-pumping of the aquifer and the resulting decrease in artesian head, consequent de-watering of the clays and silts which leads to compaction and loss of volume and consequently to land subsidence, has accelerated this phenomenon.

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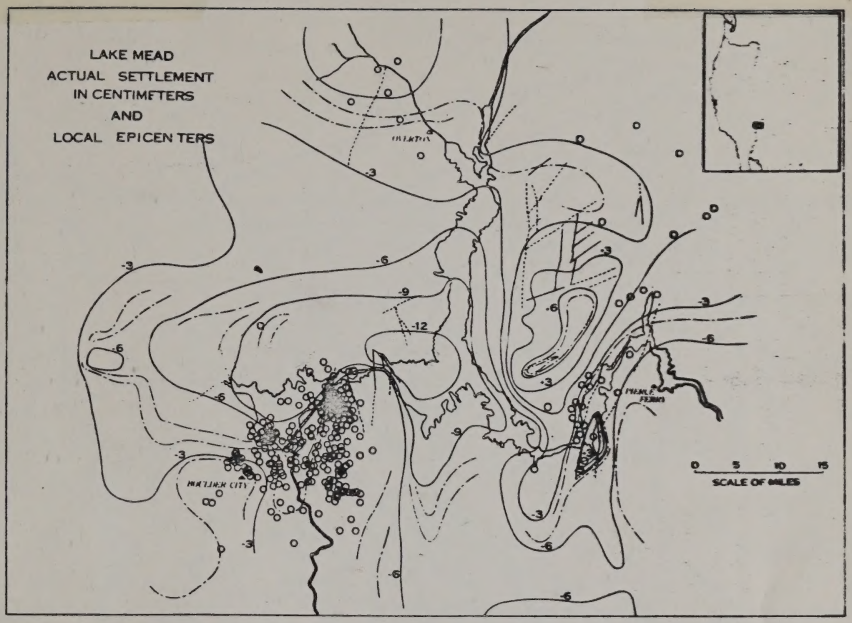

FIGURE 1 Epicenters of earthquakes in the Lake Mead area and settling of the surrounding land surface, 1940–1947 (*Carder and Small, 1948*).

Map #4 (Joint Panel on Seismology, 1972)

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Map #5 (from: Mindling, 1971)

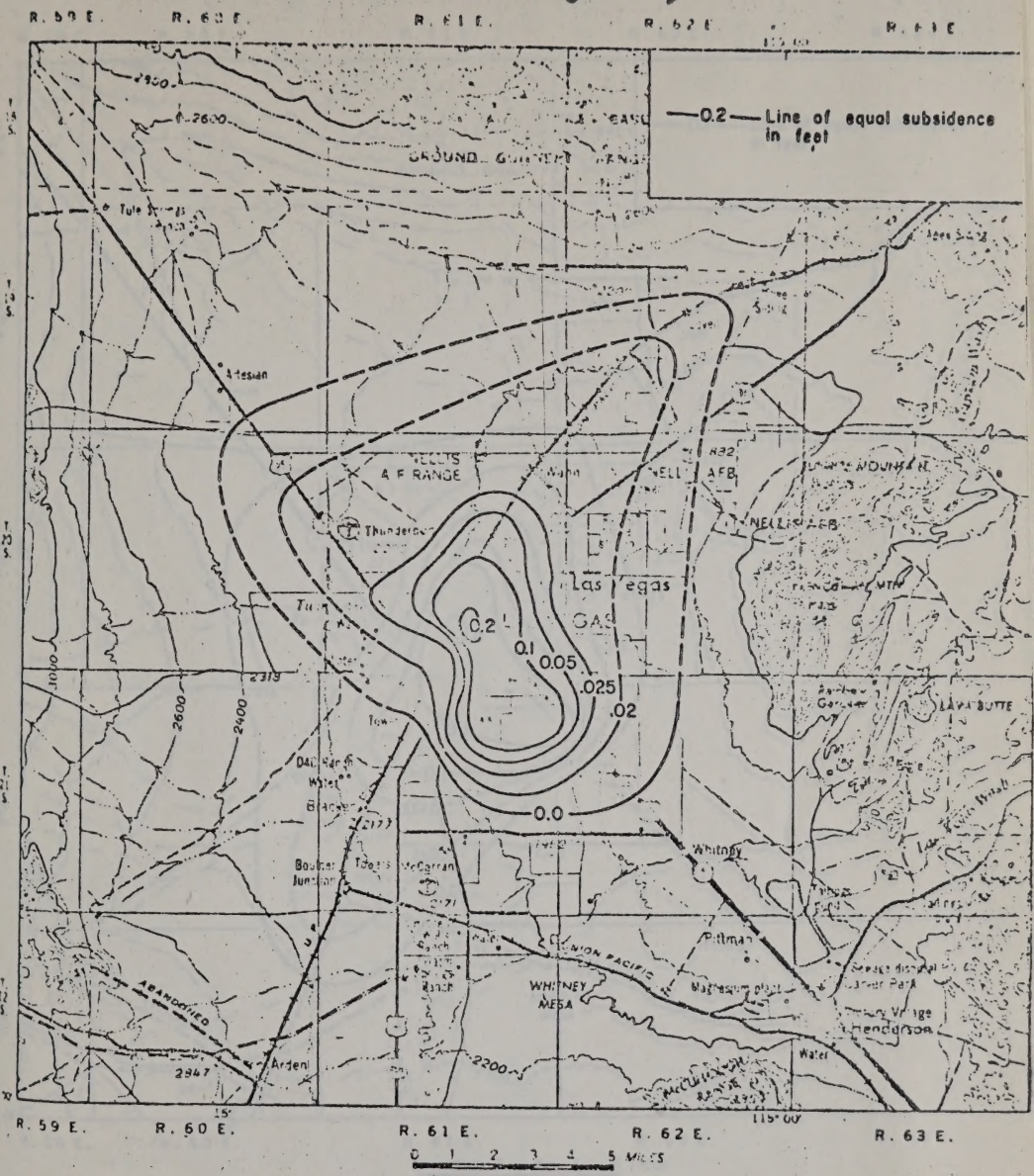


Figure 4 Land Subsidence in Las Vegas Valley Between 1935 and 1941 Due to Artesian Head Decline

Map #6 (from: Mindling, 1971)

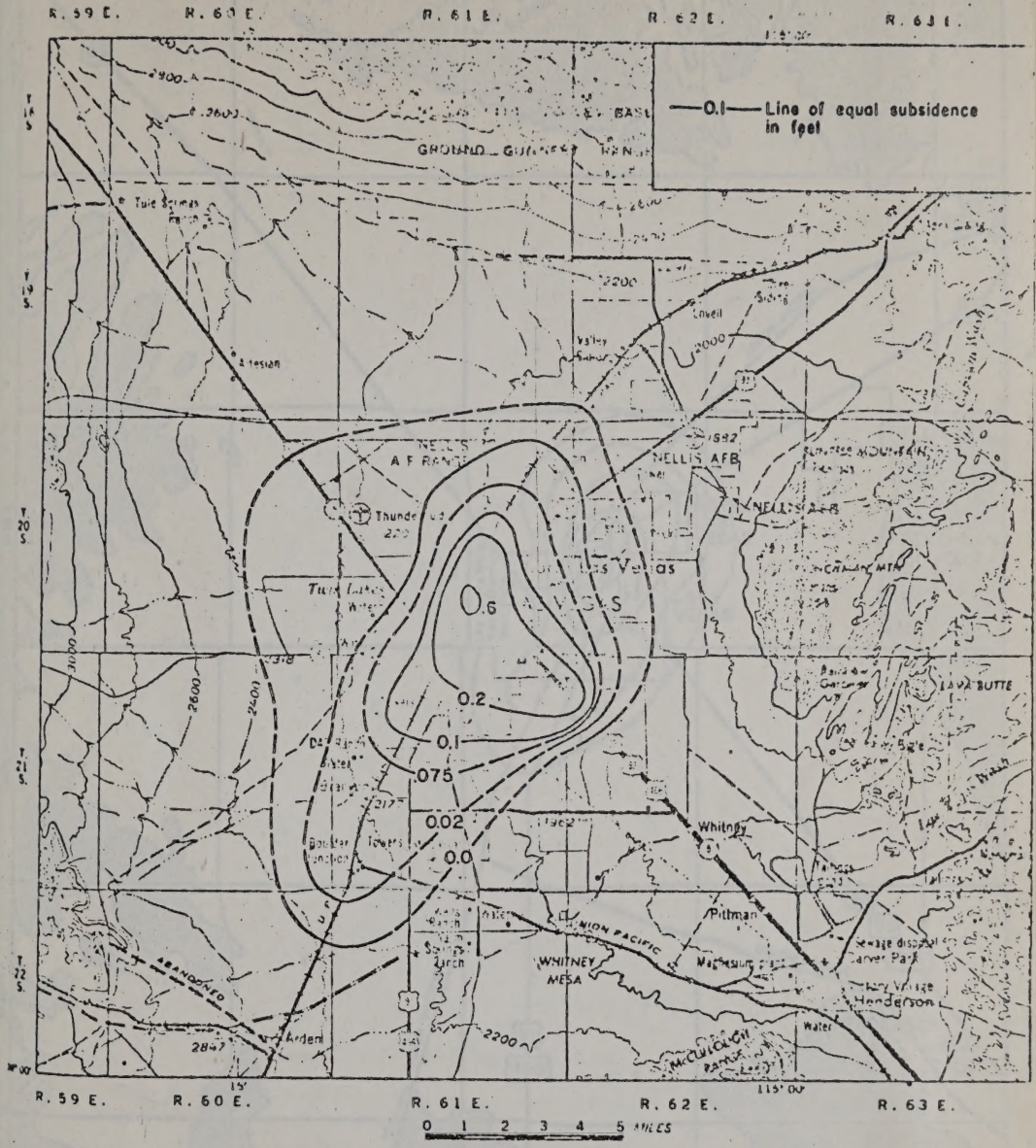
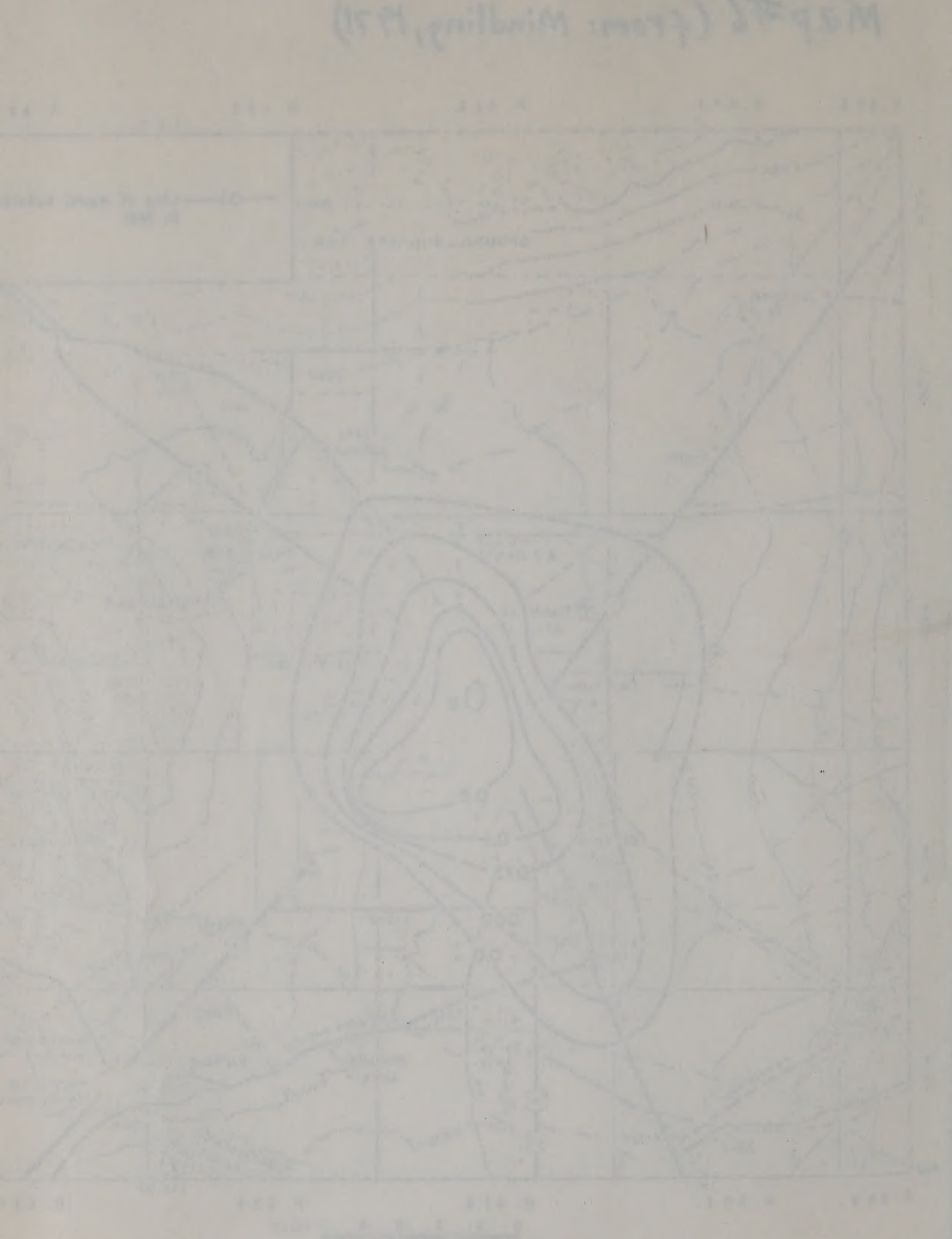


Figure 5 Land Subsidence in Las Vegas Valley Between 1941 and 1950



Map #7 (from: Mindling, 1971)

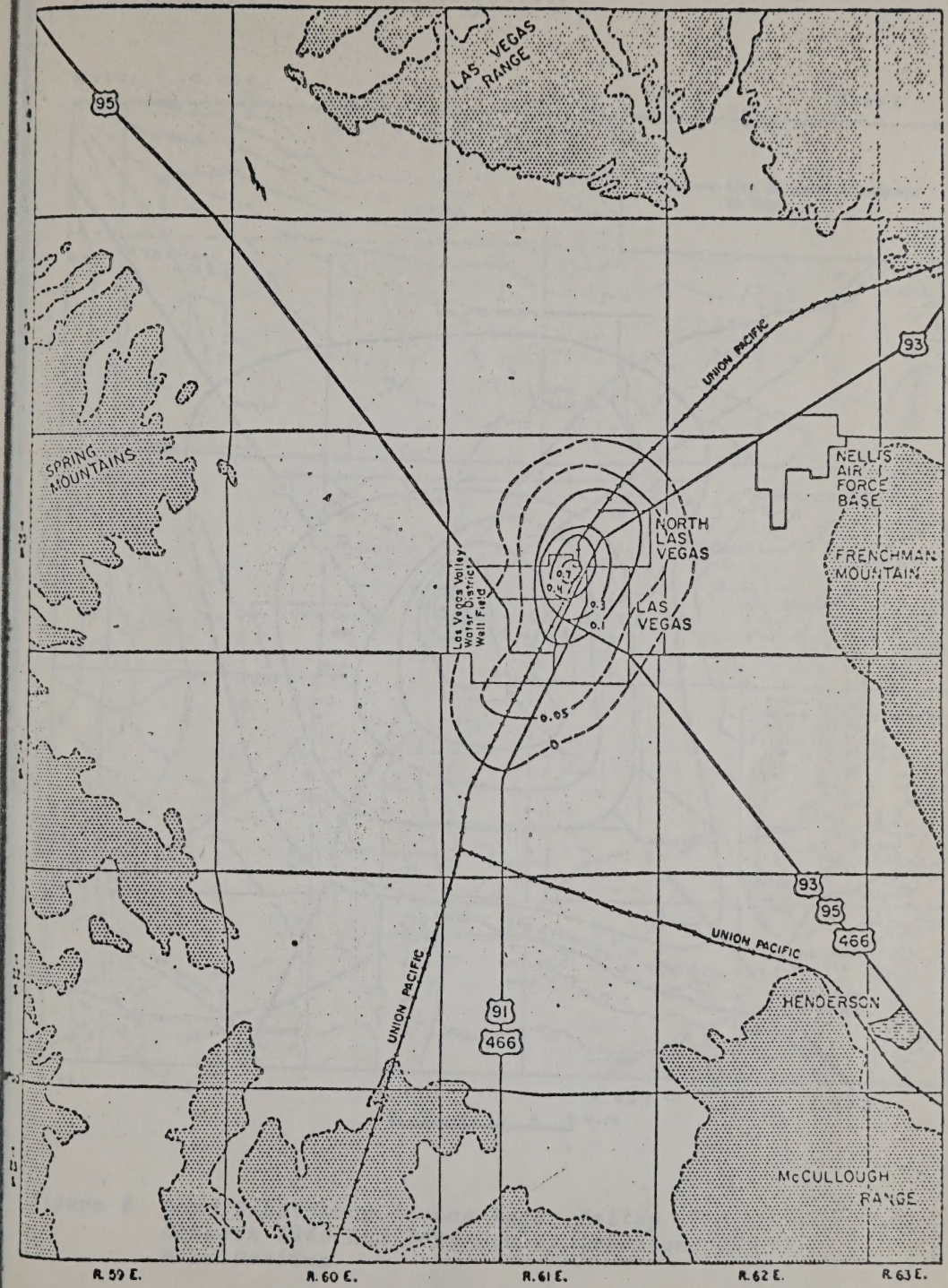


Figure 8. Land Subsidence (Ft.) in Las Vegas Valley, 1950 to 1957.

Map#8 (from: Mindling, 1971)

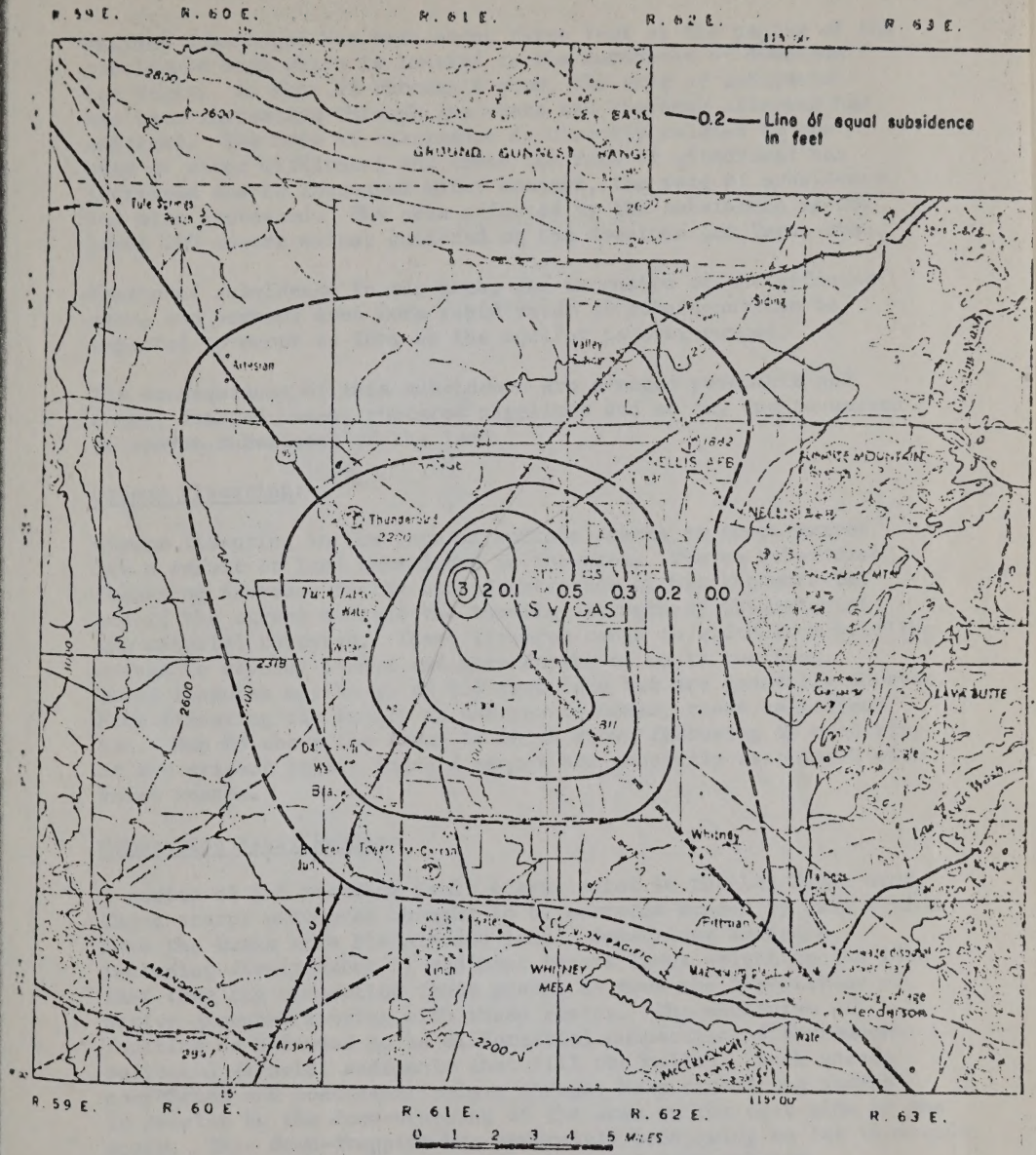
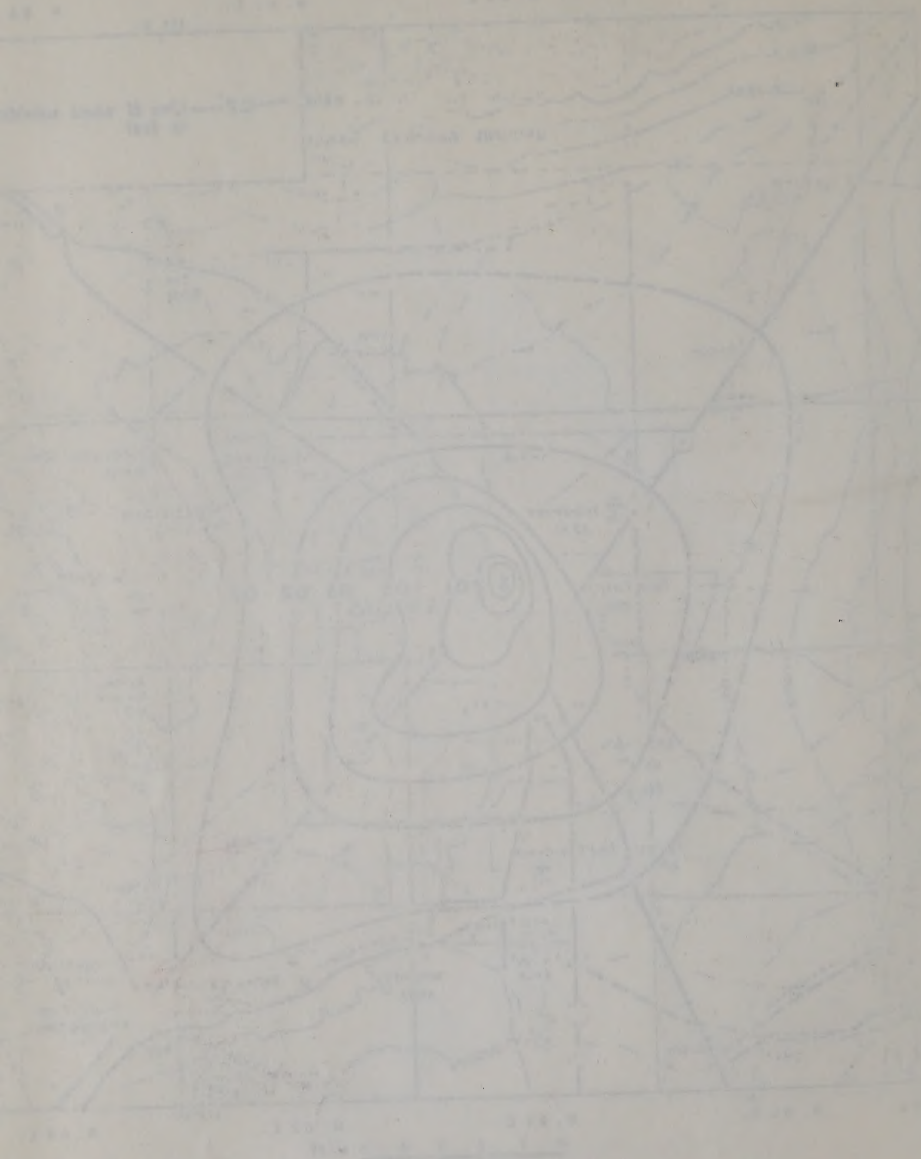


Figure 6 Land Subsidence in Las Vegas Valley Between 1950 and 1963 Due to Artesian Head Decline



Maximum subsidence has been about three feet at the center of the subsidence bowl which is located to the northwest of downtown Las Vegas. As Maps #5 through 8 show, the rate of subsidence has been increasing through the years and the area affected has enlarged. The rate of subsidence is directly related to the rate of water withdrawal and since the rate of withdrawal has increased due to increased water demands, the rate of subsidence has also increased. The area effected by the subsidence is now about 200 square miles, centered on the downtown Las Vegas area.

Continued subsidence in the area, the extension of the effected area, and perhaps even more rapid rates of subsidence can be expected to occur as long as the aquifer is over-pumped.

The consequences of this subsidence are damaged pavements and curbs, damaged homes, ruptured pipelines and so on, due to uneven or sudden subsidence of the land.

Ground Fissuring:

Ground fissuring in the form of surface cracks or crack-swarms are a result of land subsidence in the area. Uneven subsidence causes an increase in the tensile stresses within the material and if the stress exceeds the tensile strength of the material, the material ruptures. These fissures range in width from hairline cracks to several inches and have depths of up to two feet. These fissures may be up to 350 feet long but are generally shorter. Such fissuring can result in damages to homes, roads, pipelines etc. Map #9 shows the areas in which known fissuring is occurring at the present time. These fissures are generally associated with known scarps.

Compaction Fault Scarps:

A series of N-S trending fault scarps exist in the Las Vegas area. These scarps were once thought to be terraces eroded by wave action into the banks of a Pleistocene lake. Subsurface evidence, including displacement of sediment layers lends weight to the idea that they are compaction fault scarps as does the association of active ground-fissuring with these scarps. The mechanism of faulting is believed to be differential compaction of the unconsolidated alluvial sediments that fill the valley. Such uneven compaction and consequent volume changes have caused the scarps to develop by the down-dropping of the area on the east side of the scarp. This down-dropping has apparently been going on for thousands of years and is probably part of a regional down warping.

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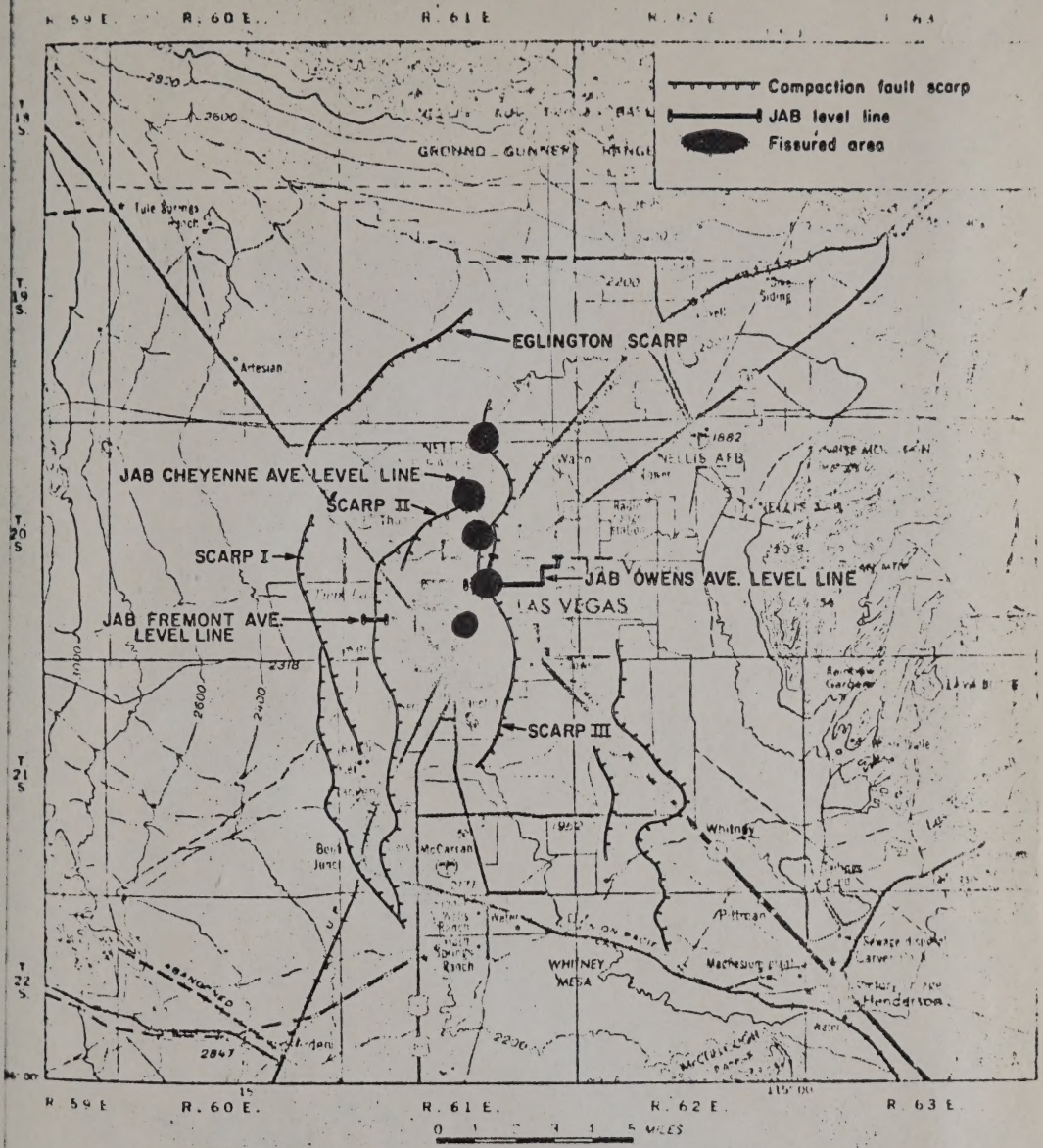

Figure 10 John A. Blume Level Lines, Compaction Fault Scarps, and Areas of Fissuring

● Fissure areas

Map #9

Fault Scarps and
fissure areas

(from: Mindling, 1971)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LAS VEGAS NW QUADRANGLE
NEVADA – CLARK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NW/4 LAS VEGAS 15' QUADRANGLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OLDER ALLUVIAL DEPOSITS

FISSURES

NELLIS AFB WELL FIELD

OLDER ALLUVIAL DEPOSITS

FISSURES

JAB CHEYENNE AVE. LEVEL AND CHAIN, LINE

27
14
IC

OLDER ALLUVIAL DEPOSITS

NORTH LAS VEGAS AIR TERMINAL

COMPACTION FAULT SCARP I

FISSURES

NORTH LAS VEGAS FISSURES

LOSEE WELL

NORTH LAS VEGAS

TONOPAH WELL

STOCKER WELL

FISSURES

JAB OWENS AVE. LEVEL LINE (EAST END)

JAB OWENS AVE. LEVEL LINE (WEST END)

COMPACTION FAULT SCARP I

COMPACTION FAULT SCARP II

FISSURES

JAB FREMONT AVE. LEVEL LINE

LAS VEGAS

LAS VEGAS

GRAVEL PIT

OLDER ALLUVIAL DEPOSITS

INTERSTATE 15

JOHN A. BLUME AND ASSO

LOCATION OF COM
SCARP AND JAB
MONITORING SURV
LAS VEGAS, NEVA

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LAS V
7.5 MIN

FRED R. CONWELL
CHIEF ENGINEERING GEOLOGIST

URS/JOHN A. BLUME & ASSOCIATES, ENGINEERS
Sheraton-Palace Hotel - 130 Jessie Street (at New Montgomery)
San Francisco, California 94105
(415) 397-2525

OLDER ALLUVIAL DEPOSITS

FISSURES

YOUNGER ALLUVIAL DEPOSITS

NELLIS AIR FORCE BASE

NELLIS AIR FORCE BASE

NAFB

DRI COMPACTION RECORDERS

JAB OWENS AVE. LEVEL LINE (EAST END)

TONOPAH WELL

STOCKER WELL

LOSEE WELL

NORTH LAS VEGAS

LAS VEGAS

POSSIBLE COMPACTION FAULT SCARP

PROBABLE CONTINUATION OF COMPACTION FAULT SCARP

YOUNGER ALLUVIAL DEPOSITS

YOUNGER ALLUVIAL DEPOSITS

OLDER ALLUVIAL DEPOSITS

Las Vegas Wash

Flamingo Wash

Winterwood Wash

Gowan Wash

Craig Wash

Las Vegas Wash

Gravel Pits

Gravel Prospects

Golf Course

Sewage Disposal

Substation

Water Tanks

Trailer Parks

Drive-in Theater

Radio Towers

Cemetery

Schools

Shopping Centers

Hospitals

Fire Stations

Post Office

Reservoirs

Water Tanks

Wells

Mountain View Park

Winterwood Park

Jaycee Park

Sunrise Station Powerplant

Craig Road Speedway

Stardust Country Club

Las Vegas Village Shopping Center

Sunrise Hospital

Valley Hospital

Womens Hospital

Las Vegas High Sch

Rancho High Sch

Western High Sch

Valley High Sch

Fremont Jr High Sch

Knudson Jr High Sch

Martin Jr High Sch

Von Tobel Jr High Sch

Bridger Jr High Sch

Lincoln Sch

Cahlan Sch

Craig Sch

Manch Sch

Variety Sch

Sunrise Acres Sch

Beckley Sch

Bracken Sch

Ronnow Sch

Squires Sch

Williams Sch

Woodlawn Cem

Municipal Court

County Juvenile Court

Fire Station

Substation

Post Office

Sewage Disposal

Control Tower

Radio Towers

Trailer Parks

Drive-in Theater

Golf Course

Gravel Pits

Gravel Prospects

Water Tanks

Wells

Mountain View Park

Winterwood Park

Jaycee Park

Sunrise Station Powerplant

The down-dropped side is always the eastern flank of the scarp, indicating a regional down warping to the east. These scarps may be as much as 100 feet high and cut across not only the unconsolidated sediments but well-cemented caliches as well. These scarps may be inactive at the present time, but fissuring near them and continued land subsidence indicates that compaction is still occurring due to aquifer pumping. This continued compaction may reach a point when enough stress is built up to make the scarps active again. Map #9 shows the location of these scarps.

3. Flooding:

Any low spot in the topography is subject to flooding during and after rains. In southern Nevada where many of the valleys are closed and have no exterior drainage, the valleys bottoms or centers which are usually marked by playa deposits can be expected to flood periodically. Old sand and gravel pits, quarries, or areas in which excavation has occurred also will be subject to flooding, as is the ground-subsidence bowl of Las Vegas (see Ground - Subsidence section).

River flood plains are periodically innudated by flood-water during and after intense storms. The Virgin River and Muddy Creek flood-plains as well as portions of Las Vegas Wash as should therefore, be considered as flood-prone areas. Table #1 shows the available records for these areas. This information is from the U.S.G.S. Water Resources Data for Nevada report (1972).

Table #1

FLOOD RECORDS IN THE STATELINE VIRGIN-VALLEY RESOURCE AREAS

Location	Maximum Discharge (c.f.s.)	Gage Height (Feet)	Date
Muddy River at Glendale	-	30	03-26-06
	7,380	20.36	11-06-60
Muddy River near Moapa	5,100	12.35	09-07-67
Virgin River at Riverside	6,140	4.70	08-15-71
Lee Canyon near Charleston Peak	880	3.60	07-28-69
Las Vegas Wash at No. Las Vegas	1,170	3.58	09-25-67
Las Vegas Wash near Henderson	1,400	4.70	08-21-57
Las Vegas Wash near Boulder City	1,050	7.51	06-26-64
	1,700	10	1964-1969
Flamingo Wash at Maryland Pky.	1,500	7.55	09-12-69

R. Sulenski, 11-30-73

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In the Lower Colorado Region which contains most of Arizona and a good deal of southern and eastern Nevada, most of the land suitable for general development is subject to some degree of flood damage, either from a defined stream or by overland flow, according to the Pacific Southwest Inter-agency Committee for the United States Water Resource Council (1971). The average annual flood damage for this region was estimated at $41 million in 1965 by the Committee. Without flood control programs, an annual flood damage of $310 million can be expected in the year 2020, according to their estimates. Implementation of a complete flood protection program will reduce these losses to about $68 million.

Flood control channels are contemplated for the Las Vegas Valley, but these plans have not as yet been implemented and it will be years before adequate protection is available.

Until such time as such protection is available, restriction of use in flood-prone areas is the only reasonable alternative to no protection at all. The area from which residential buildings are excluded will depend upon whether the 20, 50 or 100 year flood area is used as the criteria. McHarg (1969) recommends the 50 year flood zone, but the "Flood Hazard Evaluation Guidelines for Federal Executive Agencies" specifies the 100 year or 1% probability zone. The three considerations under these guidelines that would be pertinent to the valleys of southern Nevada are:

a. Residential buildings, whose occupants may not have adequate warning or means of escape during floods, cannot be placed below the elevation of the 100-year flood. (The 100-year flood would be exceeded once in 100 years, on the average, or have a 1% chance of occurrence in any year.)

b. Residential buildings, whose occupants may not have adequate warning or means of escape during floods, cannot be placed in a riverine floodway.

c. Debris cone (alluvial fan) areas require careful evaluation to determine the degree of protection required for developments.

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Map #10 shows the approximate boundaries of the flood-prone areas in the Las Vegas-Boulder City area. Data is from Tueller et al (1972), Corps of Engineers (1967). As previously indicated, the subsidence-bowl centered on Las Vegas as described by Mindling (1971) is also flood-prone.

4. Flash-Flooding:

In southern Nevada, the greatest flood hazard is the danger of flash-flooding during and after storms. The braided nature of the washes crossing the alluvial fans and the large size of the boulders within the washes indicate that water moving at a high carrying or material-moving capacity sporadically fills these washes.

Braided streams characteristically have wide channels which shift rapidly during and after heavy rains (Leopold et al, 1964). Such streambed shifts in conjunction with rapidly moving water either in the washes or overland present a real hazard to residences and other buildings which might be constructed on alluvial fans.

Little work has apparently been done on the flood hazards in the Las Vegas area (Corps of Engineers, 1967), but a flash flood which occurred in 1969, reportedly swept across the Caesar's Palace parking lot and carried at least one VW bug some distance downstream with it. The management of Caesar's Palace has put up signs warning against parking in the area through which the flood passes. This flood was apparently not even a 50 year flood, but was more likely a 10 to 20 year flood.

These floods develop very quickly and there may be no indications of rain in an area through which such a flood passes. Rain in the mountains will quickly flow off of the largely bare rocks, gather speed as it moves downslope and join up with the water draining other parts of the mountains. By the time the water reaches the mouths of canyons and moves onto the alluvaial fans that flank the mountains it may be moving quite rapidly, be of a large volume and be carrying a load of boulder-sized or larger materials with it. It will continue its movement until it is either ponded or drained into another body of water. Such floods may pass across or through large areas that haven't even been sprinkled on by the storm.

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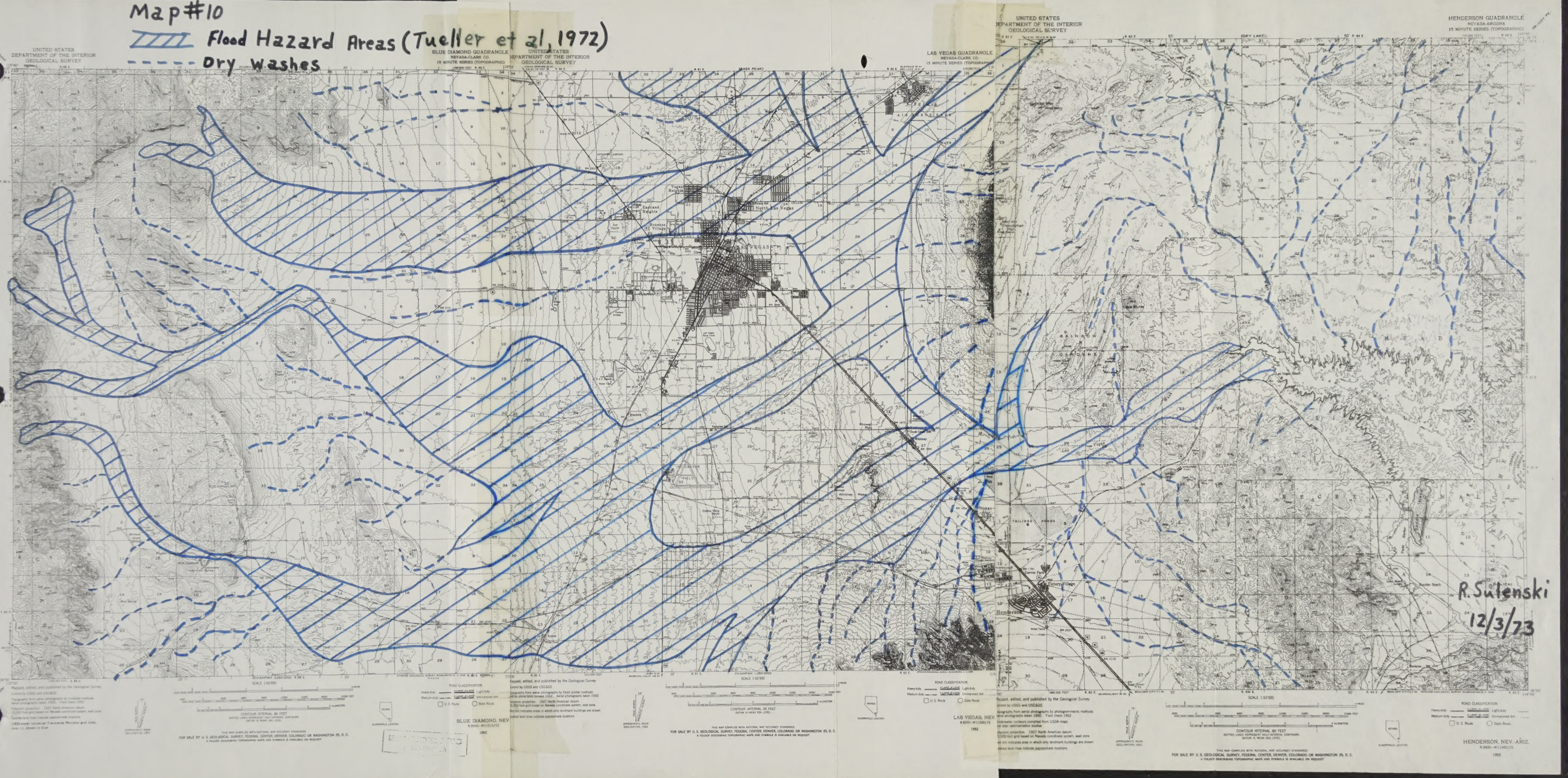
Flood Hazard Areas (Tueller et al, 1972)

Dry Washes



R. Sutenski
12/3/73

Any dry wash therefore, has some potential for flash-flooding, but the chances increases with the size of the wash which is determined by the area it drains and hence the volume of water that passes through it. The most severe flash-flood hazard areas are shown on the Physical Hazards overlay, but as previously noted every wash has some flash-flood potential and a house may be destroyed by less than a high-hazard flood if it is in or along a fairly deep or wide wash.

In a broad sense, therefore, the entire Stateline-Virgin Valley area can be considered to be flash-flood prone. Some areas are more hazardous however, due to the presence of major drainages or because of the high populations and number of homes etc. in or close to them.

Most flash-flooding in the Stateline-Virgin Valley area is associated with convective summer thunderstorms but the flood season extends from July to May (Cooley et al, 1973). Floods associated with thunderstorms seldom last more than one day according to these authors. As part of their study the authors obtained descriptions of past floods from residents and newspapers. The following is a summary of their data:

July 23, 1923 - a 45 minute storm that flooded almost every building in Las Vegas.

August 31, 1931 - washed out the Salt Lake Highway, the Boulder Highway and all roads to the west of town.

October 12, 1947 - many homes flooded

June 13, 1955 - about ½ of all the homes in the area were damaged especially on the west side of town.

July 24, 1955 - most of Las Vegas was flooded. Damage was highest in western Las Vegas, and the West Charleston, Tonopah-Twin Lakes, and Bonanza Village areas.

R. Sulenski, 11-30-73

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July 24, 1953 - west of Las Vegas was flooded. Damage was highest in western Las Vegas, and the West Charleston, Tonopah-Twin Lakes, and Bonanza Village areas.

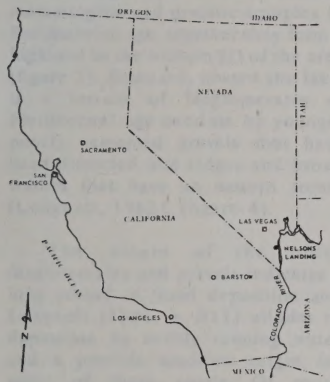
The FLASH FLOOD
at Nelsons Landing, Clark County, Nevada

GEORGE B. CLEVELAND
Geologist

CALIFORNIA DIVISION OF
MINES AND GEOLOGY

INTRODUCTION

On 14 September 1974 a flash flood occurred at Nelsons Landing, a small settlement on the shore of Lake Mohave, 40 miles southeast of Las Vegas, Nevada. Destruction of the community was nearly complete and 9 lives were lost. Flash floods, and the debris flows and mudflows that often accompany them, are common in the broad desert region of the southwest. Nearly a quarter of the area of California is included in this region. If desert areas were populated as densely as other environments, losses such as those that occurred at Nelsons Landing would be relatively frequent. Nevertheless, with the steadily increasing use of the desert, this largely ignored geologic hazard will gain greater respect as a threat to life and property.



THE SETTING

Nelsons Landing lies on the west shore of Lake Mohave near the drowned mouth of Eldorado Canyon. The lake is formed behind Davis Dam, on the Colorado River, approximately 60 miles south of Hoover Dam. Nelsons Landing and Lake Mohave are in Lake Mead National Recreation Area, which is administered by the National Park Service.

Table 1. Area of Eldorado Drainage Basin

Drainage	Area1/	Percent	Ratio2/
Eldorado3/	14.72	67.52	3.54
Eagle	4.16	19.08	1.00
Techatticup	2.92	13.40	0.70
Eldorado, total area	21.80	100.00	

1/In square miles
2/Size ratio using Eagle as unity
3/West of confluence with Eagle and Techatticup

Eldorado Canyon is the main drainage of an elongate-shaped basin which covers about 22 square miles and heads in the Eldorado Mountains 10 miles west of Nelsons Landing (figure 1). The Eldorado drainage basin (table 1) is comprised of three sub-basins: Eldorado basin proper, flanked on the south by Eagle basin, and on the north by Techatticup basin. The two latter basins converge with Eldorado 1|1/4 miles and 1 mile, respectively, above Nelsons Landing (figures 1 and 2). The elevation of the water surface of Lake Mohave is 632 feet; the maximum elevation in the highland area is 4674 feet at a point near the western edge of the Eldorado basin. Therefore, the gross slope of the basin is approximately 13:1 or nearly 5 degrees.

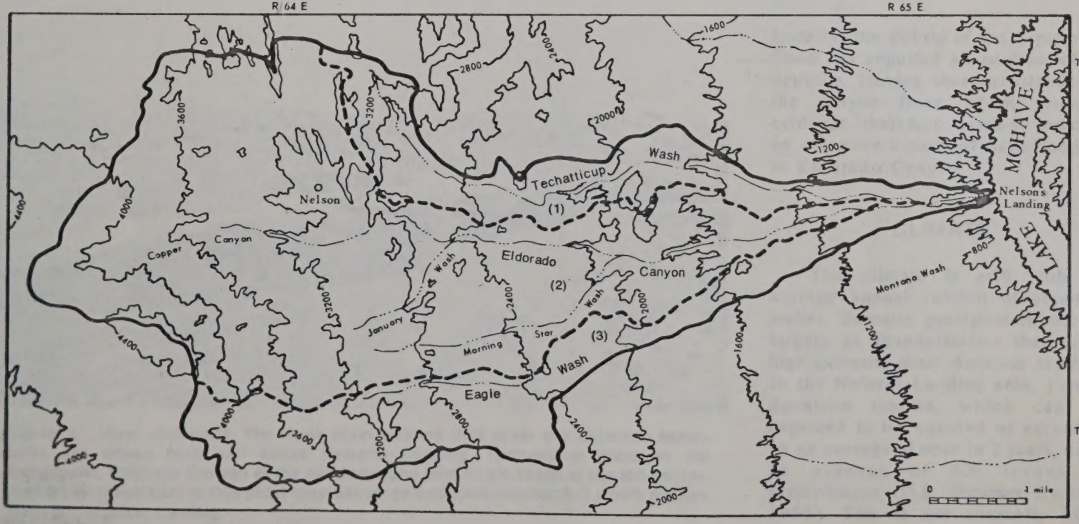
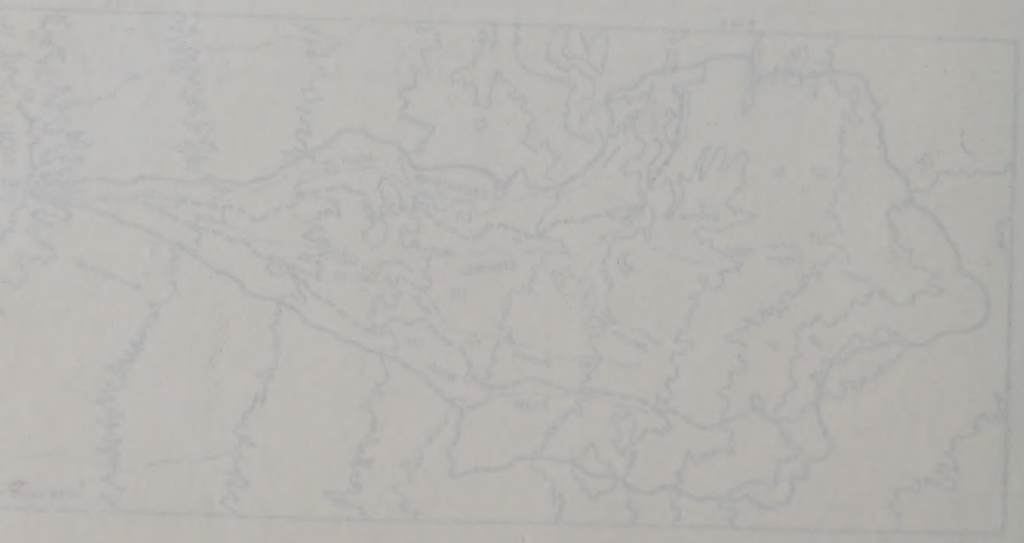


Figure 1. The Eldorado drainage basin is comprised of 3 sub-basins: (1) Techatticup basin, (2) Eldorado Canyon basin proper, and (3) Eagle basin. Topography from Nelson and Mt. Perkins quadrangles (15 minute series), U. S. Geological Survey.



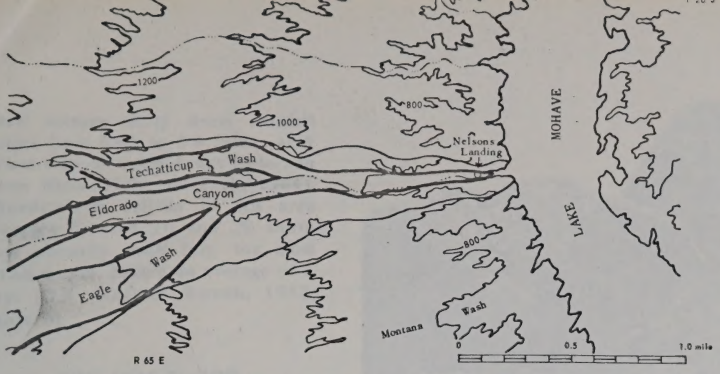


Figure 2. The three main sub-basins are combined into 1 narrow channel a short distance west of the community of Nelsons Landing, causing concentration of runoff. Topography from Fire Mountain quadrangle (7.5 minute series), U. S. Geological Survey.

GEOLOGIC HISTORY

The rocks in the basin are characterized by bright colored volcanics of Tertiary age and a dark colored metamorphic and granitic complex of Precambrian age; together they form a highland in the western 2/3 of the area (figure 3). Eastward, toward the lake, is a terrain of fanglomerates of Pleistocene? age overlain by younger poorly cemented gravels that have been dissected into ridges and broad washes that have an eastern trend. (Longwell, 1963); (figure 4).

The nature of the older fanglomerates and gravels indicates a long period of flood deposition and Longwell (1963, p. E11) alludes to deposition by swiftly running water and a possible mudflow origin for some of these rocks. Of more significance to the September 1974 flood, however, are the geologic relationships between these relatively older rocks and the modern alluvium. Near Nelsons Landing, blocks of the older rocks have fallen away from the canyon wall in the past and dropped down on the surface of the alluvial deposits that mantle the canyon floor. In this manner the alluvial debris has been partly buried and preserved. Gravel, boulders, and sand of later floods have been subsequently banked up against these blocks on their upstream side. From such exposures several generations of flood deposition are apparent (figure 5).

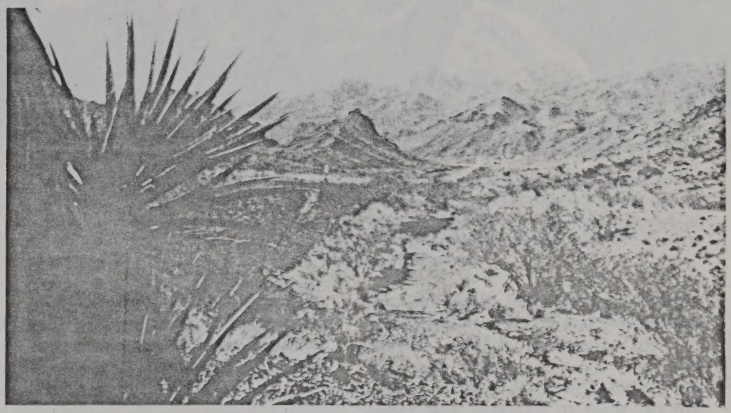


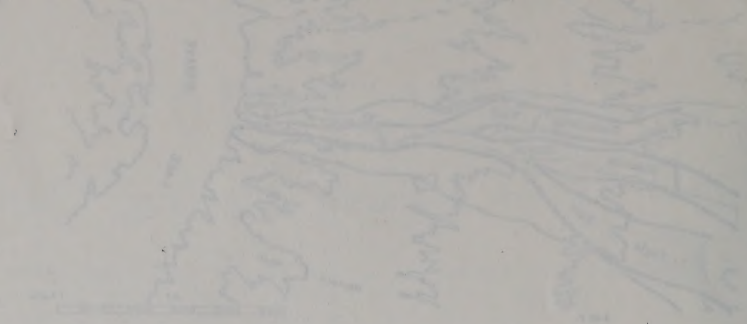
Figure 3. View east. The highland area of metamorphic and volcanic rocks west of Nelsons Landing was a collecting area for the heavy precipitation that rapidly ran off toward Lake Mohave during the storm of 14 September 1974. The old mining town of Nelson can be seen in the middleground.

Figure 4. View southwest. The three main washes that drain the Eldorado Mountains are shown here just above Nelsons Landing: Techatticup Wash in the foreground, Eldorado Canyon in the middleground, and Eagle Wash at the left center. A short distance east of this point they converge and form one conduit which passes through Nelsons Landing.

Locally, the debris of the September flood has engulfed all of these older deposits, leaving them as islands on the canyon floor. Much geologic evidence, therefore, exists to indicate an extensive history of flash flooding in Eldorado Canyon.

CLIMATE

The climate is arid with an average annual rainfall of about 5 inches. Summer precipitation occurs largely as thunderstorms that bring high intensity-short duration rainfall. In the Nelsons Landing area, 1-hour duration storms, which can be expected to be equaled or exceeded on an average of once in 2 years, drop an average of 0.6 inches of precipitation (U.S. Weather Bureau, 1953). This is not unusually high,



since average daily storm rainfall ranges from 0.08 to 2.9 inches at 7 desert stations in the lower Colorado River basin (Hely and Peck, 1964). Thunderstorm activity in this area averages between 10 and 20 storm days annually, with July, the most active month, having an average of 6 days (U.S. Weather Bureau, 1952; figure 6).

THE 1974 FLOOD

Early on the day of the flood, the weather was clear and warm with no evidence of an impending storm. By noontime clouds began to gather over Eldorado Valley, a broad desert lowland that flanks the Eldorado Mountains on the west. As the storm developed it moved northward and then abruptly turned eastward over the Eldorado Mountains towards the Colorado River. At the old mining town of Nelson, 7 miles west of Nelsons Landing, a light rainfall began about 1:30 PM. The storm reached Nelsons Landing not long afterwards — continuing to build in intensity. Heavy rainfall began high in the mountains around 2:00 PM accompanied by hail that was reported to have reached 3/4 inch at Nelsons Landing. Hail at Nelson mantled the steep slopes surrounding the town and persisted in shady places until evening. As the storm grew, flooding began in the highland area in the vicinity of Nelson near the head of Eldorado Canyon. Because the canyon at Nelson is relatively broad, the town site was not seriously affected, although flood waters covered roads with debris and damaged earthworks northeast of the town. Below the town, where the canyon narrows, the flood water rose higher and carried with it a heavy load of sand and gravel and some boulders. The numerous secondary drainage courses in the highland area funnelled their runoff into the three main trunk drainages, all of which drain eastward toward Nelsons Landing. The storm front likewise moved eastward depositing increasing amounts of rainfall on the floodwaters. Bucket measurements of precipitation made by the National Weather Service indicate that the rainfall above Nelson was about 2 inches, increased to 2.5 inches at Nelson and, farther eastward toward Nelsons Landing, reached 3 inches or more(figure 7).

Figure 5. At Nelsons Landing well cemented blocks of sandstone, that caved off the canyon walls, have covered and preserved gravel and boulder debris of past floods. Subsequent flood waters have banked up younger debris against these blocks on their upstream side (right of photo). Much geologic evidence here and in other parts of Eldorado Canyon suggest a long history of flooding.

As more and more runoff reached Eldorado Canyon from its tributaries, a pulsating character was set up in the waterflow and observers reported wave-like surges.

When the flood reached lower elevations much of its dramatic character was lost as it spread out into broad washes with gentle gradients. A few thousand feet west of Nelsons Landing where Eagle and Techatticup Washes add their flow to that of Eldorado Canyon and all enter one narrow channel (figures 2 and 4), the water flow regained its vigor. At this point too, the single narrow channel cuts down through the loose gravels into the more resistant underlying rocks (figure 8).

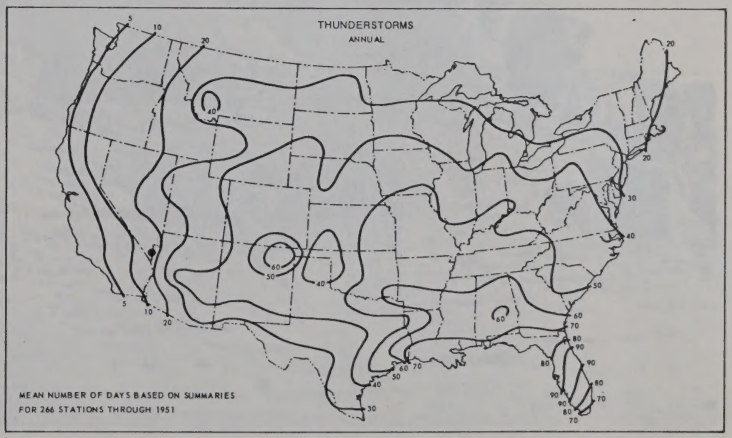


Figure 6. Annual number of thunderstorm days in the United States compared with number in the Nelsons Landing area. (From U. S. Weather Bureau Technical Paper No. 19).

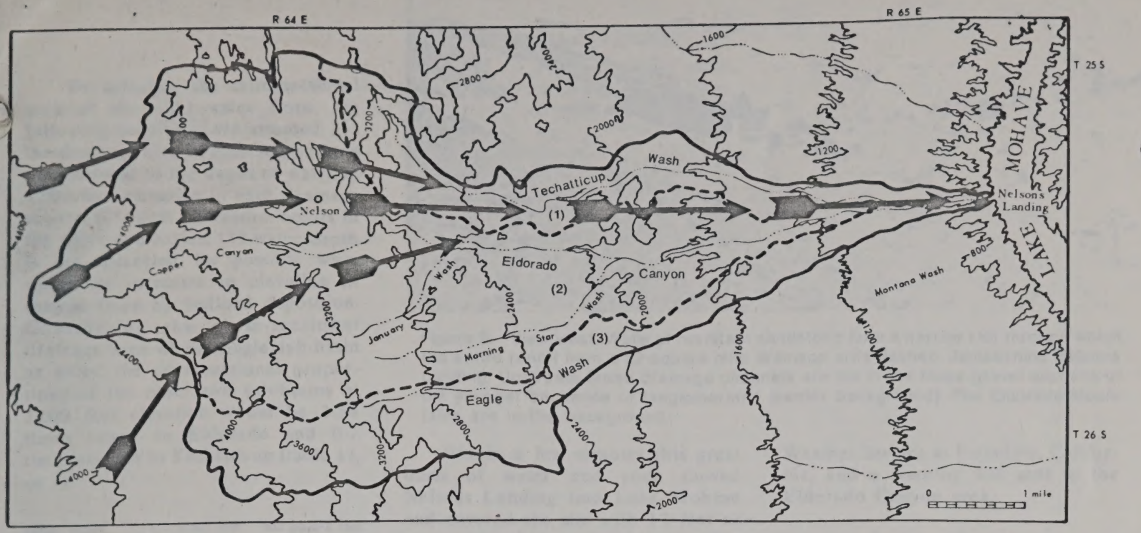


Figure 7. Approximate track of the storm, 14 September 1974. About noon clouds gathered over Eldorado Valley. As the storm developed it moved northward, then turned abruptly eastward passing over Eldorado Mountains toward Colorado River. Rainfall began about 1:30 P M at Nelson, 7 miles west of Nelsons Landing, and the main surge of flood water reached Nelsons Landing about 2:22 P M Rainfall above Nelson was about 2 inches and increased to 2.5 inches at Nelson and eastward toward Nelsons Landing. The 1-hour storm dropped more than 1/2 of the average annual precipitation.

An electric clock at Nelsons Landing stopped at 2:22 PM, about the time some eyewitnesses observed that the main surge of flood water reached the settlement. When the main surge approached Nelsons Landing, it passed below an elevated remnant of the canyon's former flood plain along its south bank and headed into the steep, narrow erosional slot, the main area of the community (figure 9). The flood waters dragged along a bedload of mainly gravel-size debris and a few boulders, some as much as 4 feet in greatest dimension, adding to the density of the flow and to its destructive capability.

Considerable speculation exists regarding the crest of the flood at the landing. Some observers reported unrealistic heights of the water surface, which probably can be attributed to the many dramatic events and general confusion that accompanied the flood.

Some mobile homes parked only a few feet above the floor of the canyon were not reached by the flood waters. Yet elsewhere downstream, floating debris was carried up to about 30 feet, perhaps by surges of water meeting natural obstacles along the canyon walls. Moreover, as flooding continued, a progressively deeper sedimentary blanket of debris was deposited on the canyon floor, and subsequent flood water would have ridden atop these deposits adding to its apparent height. The debris deposits are at least 12 feet deep at the landing.

The flood crest can be estimated roughly by measuring the cross-section of the flow in one of the tributary canyons where the geologic conditions are more clearly discernible. In Eagle Wash, 1 mile above the confluence with Eldorado Canyon, a clearly marked cross-section of the flood flow can be measured at an elevation of about 1200 feet. Here Eagle Wash is about 250 feet wide and the water level reached a height of about 2 feet, or a water front of 500 square feet.

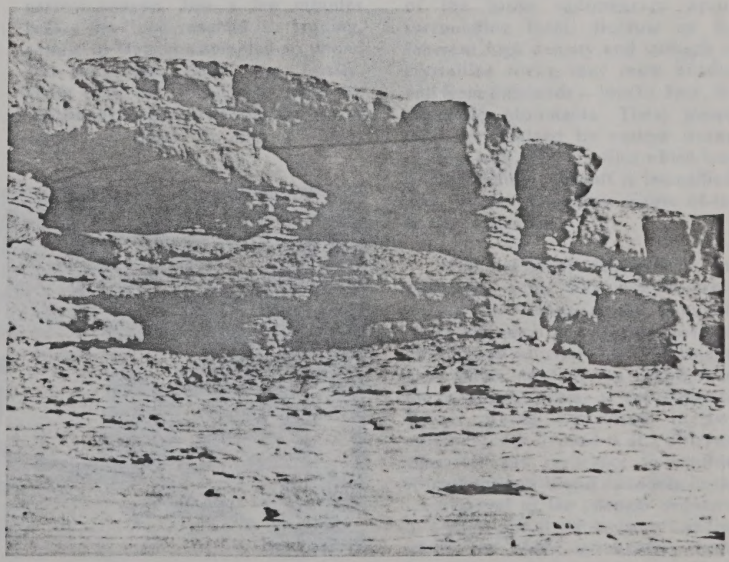
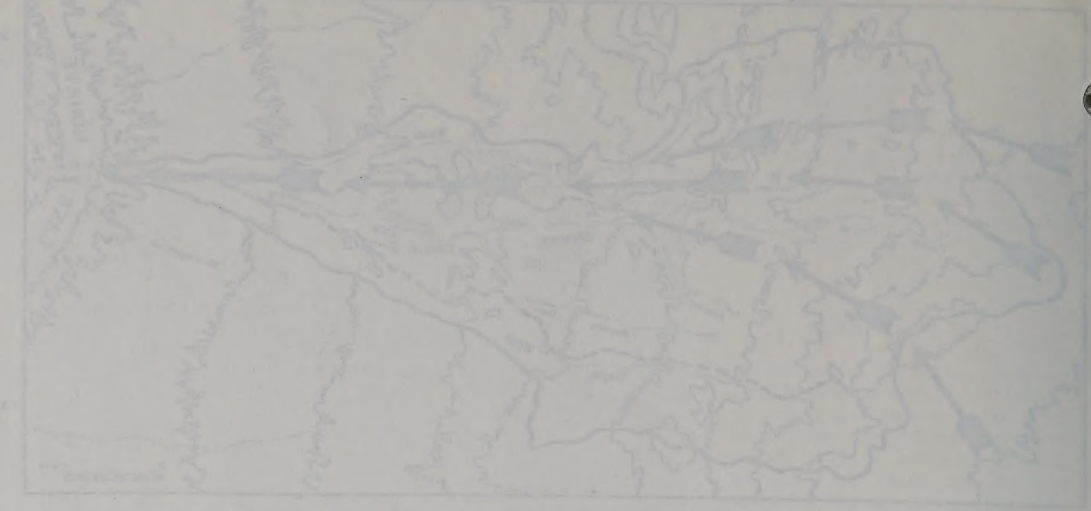


Figure 8. Resistant sandstone cliffs of the older sedimentary sequence form a narrow canyon at the site of Nelsons Landing. Household furnishings and broken parts from demolished upstream mobile homes were carried high up on the slopes by the flood waters (middleground).



To calculate the cross-sectional area of the total water front, the following conditions are assumed: (1) the drainage area of each sub-basin is proportional to the depth of water at 1200 feet elevation in each drainage course; (2) equal infiltration occurs in the three sub-basins; (3) water depth is not corrected for possible wave surges or increases in elevation of canyon floor by bedload deposition. Considering the cross-sectional drainage area of the Eagle sub-basin as unity, the cross-sectional proportions of the other two sub-basins at 1200 feet elevation would be 3.54 times larger in Eldorado and 0.7 times smaller in Techatticup (table 1), or

Eagle Wash:	1 x 500 feet	500	square feet
Eldorado Canyon:	3.54 x 500 feet	1770	square feet
Techatticup Wash:	0.7 x 500 feet	350	square feet
	TOTAL	2620	square feet

The total water flow of each channel combined into one channel just above Nelsons Landing. The minimum width of this single channel at the settlement is about 100 feet; therefore, the water was laterally confined and its height increased proportionally. The "head" of water with a total cross-sectional area of 2620 square feet was forced into a channel 100 feet wide, creating a flood crest of about 26 feet. (2620/100 = 26). Considering the numerous unknown variables inherent in this calculation, the maximum water depth probably ranged somewhere between 20 feet and 30 feet at the narrowest point in the channel.

Figure 9. View west. Walls of resistant sandstone form a narrow slot through which the entire runoff from a 22 square mile drainage area flashed, demolishing Nelsons Landing. Upstream broad drainage channels are cut in the loose gravel deposits of the younger sequence of fanglomerates (center background). The Eldorado Mountains are in the background.

Within a few minutes this great burst of water and rock shoved Nelsons Landing into Lake Mohave and covered the site with 12 feet or more of sedimentary debris. Nine people were killed and a restaurant, 5 mobile homes, 23 boats and an estimated 38 automobiles, together with 19 boat trailers, were buried in the debris. Remaining on shore were a few mobile homes that were spared, along with 26 that were destroyed, 2 damaged trucks, and the boats which were in a storage area (figures 10 and 11).

Ironically, a year ago the National Park Service recognized the hazard and warned the residents of the danger of having the town in a narrow canyon. Just a few minutes before the flood reached the landing, people in Nelson attempted to phone and warn those below and, finally, about 3:00 PM, 1/2 hour after the settlement disappeared, the storm was noted on radar by the National Weather Service at Palmdale, California, and a warning was sent to the Eldorado Canyon area.

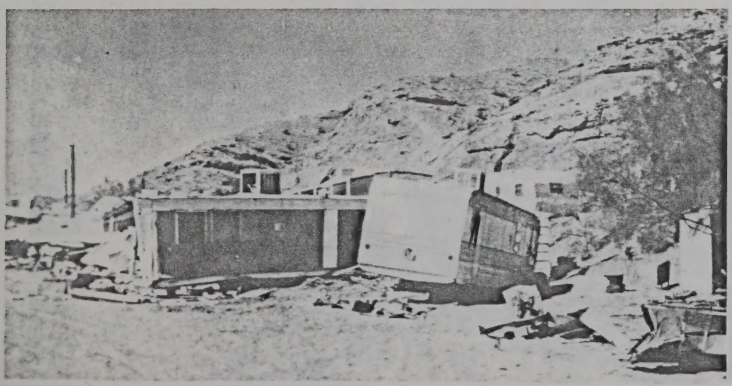


Figure 10. Damaged mobile homes, which were parked near the bottom of Eldorado Canyon when the flood swept through, were a total loss. In all, about 31 homes were damaged or carried out into Lake Mohave and lost.

APPARENT CAUSES

Several geologic and climatic conditions led to the destruction of Nelsons Landing. The most obvious are the nature of the terrain and the pattern of precipitation.

Nature of the terrain

The build up of adverse conditions began long ago with the formation of the ancient metamorphic and igneous rocks of the highland area and, much later, by the formation of the loose sedimentary apron surrounding them. Because of the inherent high density and strength of crystalline rocks, they resist erosion and form highlands — locally here, the Eldorado Mountains. These mountains are drained by narrow stream courses with steep profiles which lead to rapid runoff. Runoff is intensified, also, by the impervious nature of the rocks themselves.

The erosional debris from the highland area has accumulated around the flanks of the mountain range and, notably on the east, has formed a broad alluvial plain or bajada, over which most of the runoff from the mountains drains to the Colorado River. Being deposited in two episodes, each deposit is of a different character and resistance to erosion. Runoff follows broad channels in the weak gravel of the younger sequence to a point just above Nelsons Landing where the older sedimentary rocks have been unroofed by erosion. Here, the runoff is funnelled back into a narrow defile, piling up the water on itself and increasing its velocity.

The canyon is about 100 feet wide at its narrowest point. Near the exposed boundary between the weak and strong gravel deposits, the three principal stream courses converge and form the single conduit that accommodates the entire runoff of the 22 square mile catchment basin. Therefore, the landscape pattern was effective in concentrating, both in time and space, the heavy precipitation that occurred on the day of the storm.

Pattern of precipitation

The climate of the region and the nature of the storm contributed significantly to the magnitude of the flood. The arid climate regulates the composition and density of the plant cover and the degree of soil formation. These factors are interrelated and have a regulating effect on runoff. Because of the sparse annual rainfall the plant community is composed of relatively small and widely spaced plants. These plants offer little resistance to sheet flow of water and, being widely spaced, do little to inhibit raindrop impact. Raindrops may seal fine-grained soil particles that develop on weak sedimentary rocks, decreasing the soil's infiltration capacity and leading to increased runoff. Furthermore, in the desert, soils formed on resistant rocks, such as those exposed in the highland area, tend to be shallow and coarse-grained or rocky (lithosols) - being a product of the mechanical, rather than chemical, destruction of the parent bedrock. With little soil to blot up the rainfall, more water runs off. The nature of the ground surface is regulated in large part by the climate, which leads to conditions that favor rapid runoff. However, runoff is ultimately dependent upon the precipitation rate — even the most porous deposits and soils cannot rapidly absorb precipitation when it falls at exceptionally high rates. In the Eldorado basin, the high runoff during the storm is attributed mainly to the large area underlain by relatively impervious bedrock and to the high rate of precipitation.

The thunderstorm that yielded the heavy rainfall was in itself, unusual, providing in 1 hour more than half of the average annual precipitation. Although record 1-hour rainfall elsewhere in nearby semiarid regions may reach three times the amount that fell in the Eldorado basin, other aspects of the storm intensified its effects.

The eastward track of the storm paralleled that of the elongate direction of the drainage basin contributing much greater amounts of precipitation than if it had passed over the basin normal to the long direction. Furthermore, the rainfall fell first in that part of the basin farthest from Nelsons Landing, thus delaying its arrival there, while more runoff accumulated from the eastward-moving and continuing storm. However, some of the precipitation fell as hail and must have, to a certain extent, limited the flood crest because of the delay between the time the hail fell and the time it took for the meltwater from the hail to reach the main drainage courses.

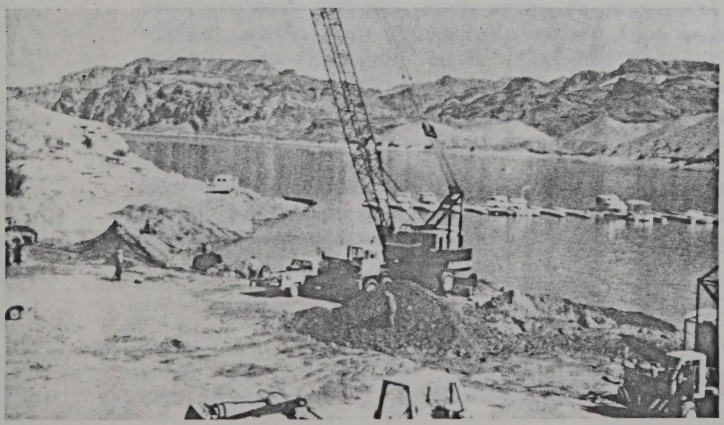


Figure 11. View northeast. The search for victims is being carried out at the mouth of Eldorado Canyon on the site of the former landing. Flood waters deposited at least 12 feet of coarse gravel in the landing area. The Black Mountains beyond Lake Mohave are in Arizona.

CONCLUSION

The lesson at Nelsons Landing is a simple one: flash flooding and debris flows and mudflows are common in the desert region. They occur in canyons or on canyon slopes, which usually provide the principal access routes for travelers through the desert. Normally water is scarce in the desert; therefore, the few places where it occurs attract people, as Lake Mohave does. The longer the canyons are occupied the greater the danger; the eventual destruction of a town built on the floor of a canyon is assured. Are people living in California's desert regions under these dangerous conditions?

ACKNOWLEDGEMENTS

This report is based on a cursory field investigation, and on the observations of the National Park Service personnel and local residents. The author is especially indebted to James Monheiser, Chief of Operations during the recovery work at Nelsons Landing, for providing details of the events that occurred at the time of the flood and for reviewing this paper.

The U.S. Geological Survey is making a geologic study of the flood and its effects.

REFERENCES

Hely, A.G. and E.L. Peck, 1964, Precipitation, runoff and water loss in the lower Colorado River - Salton Sea area: U.S. Geological Survey Professional Paper 486-B.

Longwell, Chester R., 1963, Reconnaissance geology between Lake Mead and Davis Dam Arizona - Nevada: U.S Geological Survey Professional Paper 374-E.

U.S. Weather Bureau, 1952, Mean number of thunderstorm days in the United States: U.S. Weather Bureau Technical Paper No. 19.

U.S. Weather Bureau, 1953, Rainfall intensities for local drainage design in the United States: U.S. Weather Bureau Technical Paper No. 24.

Most of these floods resulted from precipitation on the alluvial fan west of Las Vegas and which was carried by the Las Vegas Creek, Las Vegas Wash, Flamingo Wash, Tropicana Wash, and Duck Creek drainages (Cooley et al, 1973). Velocities in the drainages are estimated at from four to eleven feet per second. Velocities over three feet per second combined with depths of more than three feet are generally considered hazardous (Cooley et al, 1973). They also indicate that because of low infiltration on the calichified alluvial fan, the washes that cross the fan are also flash-flood prone since they will collect all of the water that falls on the fan.

The Kyle Canyon Fan is generally similar to the Red Rock Fan according to Cooley et al (1973) and will probably present a new flood hazard as the small-tracts in the area are built upon.

5. Geologic Hazards (Collapse Structures and Sinkholes):

Collapse structures are essentially holes in the ground which are formed as the name implies by the collapse of a rock or soil roof over a subsurface void. There are two main types of such structures that occur in the Stateline-Virgin Valley area. One type is related to solution-cave formation and roof collapse while the other is the result of "piping", a process in which uncemented material is flushed out from under more competent and cemented rocks.

Solution caves are found in areas in which the rocks or some of the rocks are soluable in water. These include limestones and other carbonate rocks such as dolomite, as well as rock salt and gypsum. Rain water over long periods of time dissolves these materials and leaves voids that are subject to roof collapse. While solution caves are generally formed in areas having appreciably more rainfall than southern Nevada, such caves do occur and are the result of higher rainfall in mountains, runoff from mountains and severe storms, and from past times of higher rainfall. In short, caves do occur in the area and such caves may be slowly enlarged. In any case, the existence of caves implies the possibility of roof collapse.

Piping is a phenomenon that is generally restricted to areas having badlands topography. Such areas are common throughout the arid and semi-arid west and consequently so is piping.

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In terms of hazards, the chances of a collapse from either solution-cave formation or piping while people are passing by is virtually nil. The chances are greater when people are permanently in the area, and greatest when buildings, etc. are on the potential collapse site. Indeed, the weight of the buildings may be enough to precipitate the collapse. This is not to say that any areas where caves or piping occur cannot be used for housing, etc. Many towns, etc. have been built over caves and mines with no problems or danger, but the presence of such voids should be considered and the potential for dangerous collapse evaluated.

Sinkholes are generally similar in appearance to collapse-structures but are the result of solution from the surface down along cracks, etc. The end result is the same but no roof collapse need be associated with its formation.

Existing collapse structures and sinkholes present a hazard in that they are generally steep-sided and fairly deep. People and/or vehicles can if such holes are not fenced or marked fall into them. Two such hazards are presently known in the area. One has been fenced for reasons other than hazard protection, while the other is completely unmarked or fenced. These two, are Devil's Hole and Devil's Throat.

Devil's Hole

Devil's Hole is a sinkhole located in the SW¼SE¼ Sec. 36, T. 17 S., R. 50 E., Nye County, Nevada. It is approximately 100' long, 20' wide, and 50' deep. It has been fenced to protect the Devil's Hole Pupfish which occurs in the water at the bottom of the hole. This fence while intended to protect the pupfish from molestation also protects the public from accidential falls into the hole. There are reportedly two other such holes in the area which presumably are unmarked (Denny and Drewes, 1965).

Devil's Throat

This collapse-structure or sinkhole is located in NE¼SW¼ or SE¼NW¼, Sec. 26, T. 17 S., R. 70 E., Clark County, Nevada. It is nearly circular with a diameter of about 80' and is about 100' deep. It is completely unmarked and unfenced. No accidents are known to have occurred at the site but that appears to be due solely to its isolated location.

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6. Sand, Dust, and Wind Storms:

All desert areas are subject to sand and dust storms and southern Nevada is no exception.

In order to produce a dust or sand storm, several factors must be present. These include high winds over long periods of time, materials that are easily eroded and carried or moved by these winds, and long stretches without obstacles that will hinder the air and debris movement. These factors most often join forces in valleys which are generally flat and which have large quantities of fine sand and silt that can be eroded and moved. All that is necessary to produce a dust or sand storm is the wind.

Areas that have been disturbed by mining, land clearing, construction, etc. and areas that contain loose materials that are not protected by desert pavements and crusts are most susceptable to erosion and provide most of the material moved by such storms.

Dust and sand storms are fairly common occurrences especially during high wind seasons (see climate portion of the physical profile). During such times dust storms intense enough to cause the street lights of Las Vegas to go on during the daylight may occur. The frequency of such intense dust storms is unknown but several have occurred within the past two years.

Such storms produce hazards in the form of decreased visibility on roads and streets and for airplanes, and may cause damage to cars, homes, etc. due to the sand-blasting effects of the particles.

High winds can be a hazard in and of themselves. Winds as high as 90 mph have been recorded in the Las Vegas Valley. Such winds can (and have) destroyed trailer homes that were not anchored, have blown campers and boats off of roads, broken windows, ripped up roofing, toppled trees etc. These same winds pose a second hazard in terms of flying debris. No deaths have apparently occurred due to high winds but injuries from flying debris and to people inside toppled trailers and campers are probably common. Property damage can be high.

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7. Swamps and Marshes

Swampy and marshy ground is not prevalent in the area due to the lack of surface water or high water-tables that are needed to form such ground. The banks of Muddy Creek and the Virgin River are in parts swampy, as is Las Vegas Wash. These areas are of limited extent, however. The Las Vegas Wash area which is close to Las Vegas and Henderson remains a swamp area due to the use of the wash as an outfall channel for the treated effluent from Las Vegas.

Small patches of swampy ground also occur around many of the springs in the area especially those that occur in clay soils. Such patches are generally extremely localized, but large areas occur in Ash Meadows.

8. Unstable Soils

Three types of unstable soils occur in the Stateline-Virgin Valley area. These are the fine "lake-sediments" found in the centers of basins, aeolian dune sand areas, and soil containing gypsum or gibbsite.

The "lake-sediments" are not inherently unstable but are extremely susceptible to erosion if disturbed. Once disturbed winnowing by wind-action may cause enough material to be eroded to threaten a building constructed on it. Homes and buildings are being constructed on such materials every day in Las Vegas, apparently without any problems, but the possibility of such a problem does exist.

Dune, aeolian, or blow sand, is an extremely loose and unstable soil type. In most areas it is thin surficial deposit but some areas such as the Las Vegas Dunes area have extensive deposits. The material has almost no structural strength and is easily eroded making construction on it hazardous. Because of the restricted areas in which this material occurs, it has not been a problem. In most areas only thin patches occur which are traps for off-road vehicles especially when covered by a thin layer of gravel which gives the deposit the appearance of stability.

The gypsum and gibbsite soils are also not common and few extensive deposits are known but because of their fluffy, talcum-powder like texture are traps for unwary drivers. They appear stable and solid and have a somewhat oily-looking surface sheen but a vehicle can become mired rapidly due to the fine, loose texture.

7. Swamps and Marshes

Swampy and marshy ground is not prevalent in the area due to the lack of surface water or high water-tables that are needed to form such ground. The banks of Muddy Creek and the Virgin River are in parts swampy, as is Las Vegas Wash. These areas are of limited extent, however. The Las Vegas Wash area which is close to Las Vegas and Henderson remains a swamp area due to the use of the wash as an outfall channel for the treated effluent from Las Vegas.

Small patches of swampy ground also occur around many of the springs in the area especially those that occur in clay soils. Such patches are generally extremely localized, but large areas occur in Ash Meadows.

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Houses built on this material run the risk of settling due to lack of support or through leaching of the gypsum through constant watering of lawns and gardens. The area to the east of Sunrise Mountain contains extensive deposits of this soil and an area is known to exist on the west side of Sunrise Mountain between Vegas Valley Drive and Monson Road along Hollywood Blvd. Other smaller pockets of such material are scattered throughout the area but have never been inventoried.

B. Man-Made Hazards:

1. Mining Hazards:

As part of the Minerals portion of the Unit Resource Analysis, a preliminary inventory of the physical hazards associated with mining and mineral exploration has been made of the resource areas. These hazards include such things as open pits and quarries, shafts, adits, tunnels, and so on. Active as well as inactive mine workings have been included whether on private or national resource lands.

These hazards are inventoried and included in the individual write-ups on the mining district or area. The figures given should be regarded as minimum figures especially in the older, inactive areas where numerous small prospect pits and shafts are likely to occur. A complete inventory of all such prospects is impracticable at the present time but should be done as time allows or when other land uses are proposed for an area.

The locations of many of the hazards are shown on the page-sized maps that accompany the mining district descriptions. These should be referred to for locations, and other information concerning these workings. Areas containing large numbers of such hazards are depicted on the Hazards Overlay, however.

2. Noise:

It has been generally acknowledged to long-term exposure to noise has harmful effects on people. The Department of Labor has specified that occupational noise levels shall not exceed 90 decibels for long periods of time nor peak above 140 decibels for short periods (Jackson, 1971). Above such levels hearing impairment may occur.

"Nuisance noise" is defined as noise whose level interferes with communication, sleeping, etc. Indoors the recommended level is from 25 to 55 decibels and outdoors from 35 to 60 decibels (Jackson, 1971).

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"Nuisance noise" is defined as noise whose level interferes with communication, sleeping, etc. Indoors the recommended level is from 25 to 35 decibels and outdoors from 35 to 60 decibels (Jackson, 1971).

Representative noise levels are as follows:

Conversational speech at 3 feet	60 decibels
Automobiles at 20 feet	70-80 decibels
Heavy trucks at 20 feet	90-100 decibels
Automatic punch press at 3 feet	110 decibels
Pneumatic chipper on drill at 5 feet	120 decibels

As can be seen automobiles and heavy trucks are above the outdoor "nuisance noise" levels as would be airplanes and railroad trains. Heavy trucks and low-flying planes can easily pass from "nuisance noise" producers to producers of potentially damaging noise.

Traffic and airplane noise problems in the Stateline-Virgin Valley area are generally restricted to the Las Vegas area. Traffic is generally light and widely-spaced outside of Las Vegas and therefore, is not much of a problem. Airport noise is insignificant outside of Las Vegas.

Within the Las Vegas Metropolitan Area traffic noise is concentrated on a number of main arteries and tourist routes. Areas known to have high volumes of traffic and consequently high noise levels are:

1. Los Angeles Freeway from Tropicana Ave. to Fremont
2. Tonopah Highway from Fremont to Decatur
3. Salt Lake Freeway from Fremont to Nellis
4. Boulder Highway (Fremont) from Main to Boulder Dam
5. Las Vegas Blvd. (The Strip) from McCarren Airport to Fremont
6. Main Street from Las Vegas Blvd. to Fremont
7. Sahara from Las Vegas Blvd. to Paradise
8. Paradise from McCarren Airport to Sahara
9. Maryland Parkway from Charleston to Tropicana

In the same way that auto traffic noise is a problem so is railroad noise. Since commuter trains are not being run into Las Vegas, freight trains make up the bulk of the noise. Two lines cross the Las Vegas area, one from California which is along the west side of town near the Los Angeles Freeway and the other from Arizona via Boulder City and Henderson. The main switching yard is located behind the Union Plaza Hotel at Main and Fremont.

Because of the energy crisis, talk of commuter and tourist trains from Los Angeles are being considered as an alternate to automobile transportation. If such trains are put on the train noise problem will increase at least along the Los Angeles line.

R. Sulenski, 11-30-73

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There are three airports in the Las Vegas area, McCarren International, Skyhaven, and Nellis Air Force Base. McCarren, which is located on the south side of town, handles the commercial flights into and out of the area. Skyhaven, which is located on the NW at Decatur and the Tonopah Highway handles small private and some small commercial airplane traffic. The Nellis Air Force Base is located to the NE of downtown Las Vegas along the Salt Lake Freeway. It's traffic consists largely of military and training craft including the latest in jet fighter planes.

It is difficult to estimate the noise influence zone of the airports, but a rule of thumb that seems to work was used. The writer lives approximately 3 miles NE of McCarren and has experienced annoying airplane noise only occasionally when planes come in extra-low. Other people who live somewhat further from the airport have had no problems at all with aircraft noise. It would appear, therefore, that a three mile radius around the airports will include most if not all of the aircraft noise areas in Las Vegas. This 3 mile radius is what was used on the overlay.

3. Miscellaneous Man-Made Hazards (Ponds, Lagoons, etc.):

Ponds and lagoons have been or will be constructed in several localities within the Stateline-Virgin Valley Resource Areas. Such ponds and lagoons are used to hold and treat sewage, to hold contaminated water produced by electric power generators, and for the storage of mill tailings.

Such ponds are hazardous because they are generally fairly deep and have steep walls which may cause a person or animal to slip or tumble in and drown. T ailings ponds may contain aci ds or other harmful substances. The following is a list of existing or planned ponds and lagoons. The locations are shown shown on the overlay.

Location	Type of Ponds	Status
Ft. Mohave	evaporative	existing
Moapa	evaporative	planned
Searchlight	sewage	planned
Overton	sewage	existing
Mesquite	sewage	existing
Indian Springs	sewage	planned
Henderson	tailings & sewage	existing
Las Vegas	sewage	2 existing series

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U S DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT KREM065

LAS VEGAS NEVADA WATERSHED CONSERVATION AND DEVELOPMENT SYSTEM DATE 02-26-75

KREM065: TABULATED ACREAGES BY LIMITING VEGETAL-SOIL FACTOR RATINGS PAGE 228

S T	D I	P U	W A	BLM ACRES LOW(1)	BLM ACRES MED(2)	BLM ACRES HIGH(3)	OTHER ACRES LOW(1)	OTHER ACRES MED(2)	OTHER ACRES HIGH(3)	SUB-TOTAL
27	05	04	010	68167	41335	9906	1710	1220	201	122539
27	05	04	085	133880	84813	14566	3403	2280	398	239340
27	05	04	086	19660	15679	0	635	1545	0	37519
27	05	04	087	72506	73873	0	739	320	0	147438
27	05	04	088	37959	38317	6284	355	401	84	79400
27	05	04	089	40011	18812	20896	243	50	106	80718
27	05	04	090	85274	43706	0	710	430	0	130120
27	05	04	091	4362	7117	0	61	99	0	11639
27	05	04	092	21310	1890	0	0	0	0	23200
27	05	04	093	23306	23224	0	1453	538	0	48521
27	05	04	094	12856	13297	12262	108	6069	883	45475
27	05	04	095	28307	40312	11083	574	1076	119	81471
27	05	04	096	7451	7472	3972	356	398	6	19655
27	05	04	097	39576	55515	26833	371	394	135	122824
27	05	04	098	17491	14230	21346	36	56	38	53197
27	05	04	099	43400	92968	81980	545	533	682	220108
27	05	04	100	65550	97651	14717	1197	1562	91	180768
27	05	04	101	53651	10509	389	558	21	1	65129
27	05	04	102	14816	6648	7003	67	93	0	28627
27	05	04	103	16954	0	3011	160	0	0	20125
27	05	04	104	4640	0	0	720	0	0	5360
27	05	04	105	18902	6278	0	768	212	0	26160
27	05	04	106	3004	20136	0	50	570	0	23760
27	05	04	107	10870	14369	0	0	160	0	25399
27	05	04	128	10374	10871	5664	135	76	0	27120
27	05	04	129	8689	12917	0	0	0	0	21606
27	05	04	130	36237	13810	10998	626	110	104	61885
27	05	04	131	72051	65743	12706	205	59	8	150772
27	05	04	132	17425	36710	0	47	45	0	54227
27	05	04	133	22366	20150	6083	322	221	88	49230
PLANNING UNIT 04 SUBTOTAL				1011645	884352	269699	16154	18538	2944	2203332
% DISTRIBUTION OF BLM/OTH AREA				47%	41%	12%	43%	49%	8%	
% DISTRIBUTION OF TOTAL AREA				46%	40%	12%	1%	1%	0%	
TOTAL % DISTRIBUTION				LOW 47%	MED 41%	HIGH 12%				

References

Coffman, J.L., and C.A. von Hake 1972, United States Earthquakes - 1970: Nat. Oceanic and Atmospheric Admin., Bull. 1-TS6937, 81 p.

Cooley et al, 1973, Influence of Surface and Near-Surface Caliche Distribution on Infiltration Characteristics and Flooding, Las Vegas Area, Nevada: Center for Water Resources Research, Desert Research Institute, University of Nevada, 41p.

Corps of Engineers, 1967, Flood Plain Information - Lower Las Vegas Wash, Clark County, Nevada: 23p.

Denny and Drewes, 1965, Geology of the Ash Meadows Quadrangle, Nevada - California: USGS Bull. 1181-L, 56p.

Jackson, W.E., 1971, Environmental Control: in Environmental Health, P.W. Purdom (ed.), Academic Press, N.Y., p. 379-429.

Joint Panel on Problems Concerning Seismology and Rock Mechanics, 1972, Earthquakes related to reservoir filling: Nat. Tech. Info. Serv., PB-208327, 24p.

Leopold, Wolman, and Miller, 1964, Fluvial Processes in Geomorphology: W.H. Freeman and Co., 522p.

McHarg, I.L., 1969, Design with Nature: Doubleday and Co., Inc., 197p.

Mindling, 1971, A Summary of Date Relating to Land Subsidence in Las Vegas Valley: Center for Water Resources Research, Desert Research Institute, 55p.

Nevada Bureau of Mines, 1970-1973, Bulletin of the Seismological Laboratory for the Period April 1 to June 30, 1970; July 1 to Sept. 30, 1970; October 1 to December 31, 1970; January 1 to March 31, 1971; April 1 to June 30, 1971; July 1 to September 30, 1971; and October 1 to December 31, 1971.

Pacific Southwest Inter-Agency Committee for the United States Water Resources Council, 1971, The Pacific Southwest Analytical Summary Report on Water and Land Resources; Water Resources Council publication, 185p.

Tueller et al, 1972, Application of EROS Data to Arid Regions: College of Agriculture, University of Nevada at Reno, 43p.

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References

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U.S.G.S., 1972, Water Resources Data for Nevada: 239p.

Water Resources Council, 1969, Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies: Water Resources Council, 45p.

Water Resources Council, 1971, Regulation of Flood Hazard Areas to Reduce Flood Losses, Vol. 1, parts I-IV: Water Resources Council, 578p.

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Mammals

Stateline-Virgin Valley Planning Units

Insect-Eaters - Order Insectivora

.... Merriam Shrew - Sorex merriami.
Uncommon. Arid areas, sagebrush, bunchgrass.
.... Gray (Desert) Shrew - Notiosorex crawfordi.
Uncommon. Arid areas, sagebrush and other low desert shrubs.
.... Inyo Shrew - Sorex tenellus.
High mountain peaks, near water.

Bats - Order Chiroptera

.... California leaf-nosed bat - Macrotis californicus.
Common. Caves, old mining tunnels.
.... California myotis bat - Myotis californicus.
Common. Mine tunnels, hollow trees, loose rocks.
.... Big free-tailed bat - Tadarida molossa.
Uncommon. Caves, cliffs, buildings.
.... Mexican free-tailed bat - Tadarida brasiliensis.
Common. Caves, buildings.
.... Pallid bat - Antruzous pallidus.
Common. Moist areas.
.... Long-eared bat - Myotis evotis.
Common. Buildings, trees.
..../Spotted bat/ - Euderma maculata.
Rare. Report any sightings.
.... Hoary bat - Lasiurus cinereus.
Common. Trees, shrubs.
.... Red bat - Lasiurus borealis.
Very uncommon. Wooded areas.
.... Big brown bat - Eptesicus fuscus.
Common. Buildings.
.... Western pipistrelle - Pipistrellus hesperus.
Caves, cliffs, buildings.
.... Silvery-haired bat - Lasionycteris noctivagans.
Forested areas, caves.
.... Small-footed myotis - Myotis subulatus.
Common. Caves, mines, forested areas.
.... Fringed myotis - Myotis thysanodes.
Caves, attics.
.... Little brown myotis - Myotis lucifugus.
Common. Caves, mines, trees, buildings.
.... Townsend's big-eared bat - Plecotus townsendi.
Caves, tunnels, buildings.

Rodents - Order Rodentia

.... Townsend ground squirrel - Citellus townsendi.
Common. Valleys.
.... Rock squirrel - Citellus variegatus.
Common. Rocky areas.
.... White-tailed antelope squirrel - Ammospermophilus leucurus.
Low desert and foothills, scattered juniper.
.... Round-tailed ground squirrel - Citellus tereticaudus.
Low desert, creosote, cactus.
.... Gold-mantled ground squirrel - Citellus lateralis.
Chaparral.
.... Least chipmink - Eutamias minimus.
Low sagebrush, pinyon-juniper. Common.
.... Cliff chipmunk - Eutamias dorsalis.
Common. Pinyon-juniper.
.... Panamint chipmunk - Eutamias panamintinus.
Pinyon-juniper.
.... Charleston mountain chipmunk - Eutamias palmeri.
Rocky slopes.
.... Porcupine - Erethizon dorsatum.
Uncommon.
.... Valley Pocket Gopher - Thomomys bottae.
Valleys, loam soil.
.... Little pocket mouse - Perognathus longimembris.
Pinyon-juniper.
.... Great Basin pocket mouse - Perognathus parvus.
Uncommon. Sagebrush, pinyon, chaparral.
.... Long-tailed pocket mouse - Perognathus formosus.
Rocky slopes, gravelly soil.
.... Ord Kangaroo rat - Dipodomys ordi.
Sandy, sagebrush.
.... Merriam Kangaroo rat - Dipodomys merriami.
Sandy, rocky soils.
.... Desert Kangaroo rat - Dipodomys deserti.
Sandy areas, sparse vegetation.
.... Beaver - Castor canadensis.
Near streams.
.... Western harvest mouse - Reithrodontomys megalotis.
Open desert.
.... Canyon mouse - Peromyscus crinitus.
Rocky canyons, arid areas.
.... Cactus mouse - Peromyscus eremicus.
Low deserts. Rocky outcrops.
.... Brush mouse - Peromyscus baylei.
Uncommon.

.... Deer mouse - Peromyscus maniculatus.
Very common. Widespread habitat.
.... Pinyon mouse - Peromyscus truei.
Rocky terrain, pinyon-juniper.
.... Meadow mouse - Microtus montanus.
Common. Dense grass.
.... House mouse - Mus musculus.
Common. Sagebrush.
.... Southern grasshopper mouse - Onychomys torridus.
Sagebrush, greasewood.
.... Desert Woodrat - Neotoma lepida.
Desert floors, yucca. Very common.
.... Bushy-tailed woodrat - Neotoma cinerea.
Rocky areas, caves. Very common.
.... Mountain vole - Microtus montanus.
Uncommon.
.... Dark Kangaroo mouse - Microdipodops megacephalus.
Sandy soil with sagebrush and rabbitbrush.
.... Pale Kangaroo mouse - Microdipodops pallidus.
Sand, scattered brush.

Hares and Rabbits - Order Lagomorpha

.... Blacktail jackrabbit - Lepus californicus.
Common. Low desert, sparse vegetation.
.... Desert cottontail - Sylvilagus auduboni.
Common. Sagebrush, pinyon-juniper.
.... Mountain cottontail - Sylvilagus nuttali.
Common. Sagebrush, loose rocks.

Carnivores - Order Carnivora

.... Cougar - Felis concolor.
Widespread in small numbers.
.... Coyote - Canis latrans.
Common.
.... Bobcat - Lynx rufus.
Common.
.... Kit fox - Vulpes macrotis.
Foothills, desert.
.... Gray fox - Urocyon cinereoargenteus.
Bushy, rocky habitat.
.... Badger - Taxidae taxus.
Dry hills, valleys.
.... Spotted skunk - Spilogate putorius.
Brushy, rocky country.

.... Striped skunk - Mephitis mephitis.
Near water.
.... Long-tailed weasel - Mustela frenata.
Near water.
.... Ring-tailed cat - Bassariscus astutus.
Cliffs, canyons, attics.
.... Raccoon - Procyon lotur.
Near water.

Even-toed Herbivores - Order Artiodactyla

.... Antelope - Antilocapra americana.
Open sagebrush plains. Uncommon.
.... Bighorn sheep - Ovis canadensis.
Uncommon. Mountain slopes with few trees.
.... Mule deer - Odocoileus hemionus.
Common. Desert shrubs, chaparral, pinyon-juniper.
.... Elk - Cervus canadensis.
Mountain meadows, foothills, valleys.

/Species / Classified "threatened" by BSF&W and/or "rare or endangered" by the State of Nevada.

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Fishes

Stateline Planning Unit

Herring and Shad - Family Clupeidae

Threadfin Shad - Dorosoma petenense atchafalayae
Colorado River, Lake Mead

Salmon and Trout - Family Salmonidae

Rainbow Trout - Salmo gairdneri
Introduced into Lake Mead and Lake Mohave

Lahonton cutthroat Trout - Salmo clarki henshawi
Lake Mead

Silver salmon - Oncorhynchus kisutch
Introduced into Lake Mead

Suckers - Family Catostomidae

Razorback sucker - Xyrauchen texanus
Status in Lakes Mead and Mohave is uncertain

Catfishes - Family Ictaluridae

Channel Catfish - Ictalurus punctatus
Lakes Mead and Mohave, Colorado River

Black Bullhead catfish - Ictalurus melas
Lakes Mead and Mohave

Killifishes - Family Cyprmodontidae

/Amargosa Pupfish/ - Cyprinodon nevadensis
Two subspecies:
Nevada Pupfish - Cyprinodon nevadensis mionectes
Big Spring - Ash Meadows

School Spring Pupfish - Cyprinodon nevadensis pectoralis
School Spring, Mexican Spring, Indian Spring, Scruggs Springs.

Devil's Hole Pupfish - Cyprinodon diabolis
Devil's Hole, Ash Meadows

Pahrump Killifish - Empetrichthys latos
Manse Ranch - Pahrump

Topminnows - Family Poeciliidae

Mosquitofish - Gambusia affinis
Warm Springs in Ash Meadows

Shortfin Molly - Peocilia mexicana
Warm Springs in Ash Meadows

Black Mollies - Mallienesia latipinnae,
Guppies - Lebistes reticulatus,
Swordtails - Xiphophorus helleri,
and Platys - Xiphophorus maculatus
Introduced into Warm Springs in Ash Meadows.

Carp and Minnows - Family Cyprinidae

/Swiftwater Colorado Gila/ - Gila elegans
Colorado River and Lakes Mead and Mohave

Golden Shiner - Notemigonus crysoleucas
Introduced into Colorado River

Amargosa Speckled Dace - Rhinichthys osculus nevadensis
Amargosa River and streams, marshes, and springs in Ash Meadows

Asiatic Carp - Cyprinus carpio
Colorado River, Lakes Mead and Mohave

Goldfish - Carassius auratus
Warm Springs

Fathead Minnows - Pimephales promelas
Lakes Mead and Mohave

Sunfish, Basses and Crappies - Family Centrarchidae

Largemouth bass - Micropterus salmoides
Lakes Mead and Mojave

Bluegill sunfish - Lepomis macrochirus
Lakes Mead and Mojave

Green sunfish - Lepomis cyanellus
Lake Mead

Black Crappie - Pomoxis nigromaculatus
Lake Mead

/Species/ - Classified as "threatened" by BSF&W and/or "rare or Endangered" by the State of Nevada

____Northern Waterthrush-R, Sh
____MacGillivray's Warbler-G, R
____Yellowthroat-A, G, R
____Yellow-breasted Chat-G, R, C
____Wilson's Warbler-G, W, R
____Hooded Warbler-Ac
____American Redstart-G, W, R
____Painted Redstart-Ac, W
____Parula Warbler-Ac
____Worm-eating Warbler-Ac
____Cerulean Warbler-Ac

WEAVER FINCHES

____House Sparrow-T, O

MEADOW LARKS, BLACKBIRDS and ORIOLES

____Western Meadow Lark-O, Sa
____Yellow-headed Blackbird-A, O
____Red-winged Blackbird-A, O
____Hooded Oriole-Ac, G, W
____Bullock's Oriole-O, R, T, G
____Scott's Oriole-O, Ch, W
____Brewer's Blackbird-Sh, O, T
____Brown-headed Cowbird-O, G, R
____Orchard Oriole-Ac, T, G
____Rusty Blackbird-Ac, G, R
____Boat-tailed Grackle-Ac, R, G, T

TANAGERS

____Western Tanager-W
____Hepatic Tanager-W
____Summer Tanager-G, W, R

GROSBEAKS, FINCHES, SPARROWS and BUNTINGS

____Cardinal-Ac, G, R, W
____Rose-breasted Grosbeak-Ac, W
____Black-headed Grosbeak-Ch, G, W, R
____Blue Grosbeak-Ch, G, R
____Indigo Bunting-Ac
____Lazuli Bunting-Sa, Ch, R
____Dickcissel-Ac, O
____Evening Grosbeak-W
____Cassin's Finch-W
____House Finch-Wi
____Pine Siskin-W
____American Goldfinch-G, R
____Lesser Goldfinch-O, Ch, W, R
____Lawrence's Goldfinch-Ac, W, Ch
____Red Crossbill-G, W
____Green-tailed Towhee-Sa, G, W, R,Ch
____Rufous-sided Towhee-Ch, W
____Abert's Towhee-R, Ch
____Lark Bunting-O, Ch, R
____Savannah Sparrow-A, Sh, O
____Grasshopper Sparrow-O
____Vesper Sparrow-O, Sa
____Lark Sparrow-O, G
____Cassin's Sparrow-Ac, O
____Black-throated Sparrow-O
____Sage Sparrow-O, Sa, Ch
____Slate-colored Junco-W
____Oregon Junco-Ch, W
____Gray-headed Junco-W
____Tree Sparrow-Ch, R
____Chipping Sparrow-Ch, W, G
____Brewer's Sparrow-Sa, Ch
____Black-chinned Sparrow-Sa, Ch, W
____Harris' Sparrow-Ac, W
____White-crowned Sparrow-Ch, G, T
____Golden-crowned Sparrow-Ch, G
____White-throated Sparrow-Ac, W, Ch
____Fox Sparrow-Ch, G, W, R
____Lincoln's Sparrow-G, R
____Song Sparrow-A, G,, R
____Purple Finch-Ac, W
____Lapland Longspur-Ac, O

NOTES

Date _____ Total _____

Observer (s) _____

Weather _____ Time _____

Prairie Falcon

Roadrunner

"THIS LAND IS YOUR LAND"

and so is the Wildlife

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Land Management
Las Vegas District Office
November 1970

Rock Wren

BIRDS

LAS VEGAS BLM DISTRICT

Located in southern Nevada, the Las Vegas BLM District includes Esmeralda, Clark and southern Nye and Lincoln Counties. Plant communities in this vast 9½ million acre public area range from desert scrub near Death Valley to pseudo-alpine atop 11,912 foot Mount Charleston. Both Mohave and Great Basin Deserts are represented.

Bird life is a greatly varied composite. Waterfowl and shorebirds are found in association with the Colorado River Systems, the Pahranagat National Wildlife Refuge (managed by the U.S. Bureau of Sport Fisheries and Wildlife), and the Overton Wildlife Management Area (managed by the Nevada Department of Fish and Game).

Isolated mountain ranges in the desert often surprise bird watchers with birds common to northern climes. Southern Nevada hosts many wintering bird species from northern areas.

BI[illegible]CHECKLIST

Las V[illegible]as BLM District

The following bird list contains 326 species which have been recorded in the District. The column at the left is provided for checking species observed.

General habitat types where the species is most likely to occur are indicated by: A-aquatic; Sh-shores, beaches, flats; O-open, fields, deserts, prairies; G-groves, thickets; Ch-chaparral, brushy; Sa-sagebrush; W-woodlands; R-riparian; C-cliffs, canyons; T-towns, Wi-widespread; Ac-accidental; *-introduced.

Birds printed [in box] are rare or endangered in the United States.

This list was compiled through cooperative assistance from the Nevada Department of Fish and Game, the University of Nevada, Las Vegas, and the Las Vegas Bird Club.

LOONS
- _____Common Loon-A
- _____Red-throated Loon-A

GREBES
- _____Western Grebe-A
- _____Horned Grebe-A
- _____Eared Grebe-A
- _____Pied-billed Grebe-A

PELICANS
- _____White Pelican-A
- _____Brown Pelican-Ac, A

CORMORANTS
- _____Double-crested Cormorant-A

HERONS & BITTERNS
- _____Great Blue Heron-A
- _____Green Heron-A
- _____Little Blue Heron-Ac, A
- _____Louisiana Heron-Ac, A
- _____Black-crowned Night Heron-A
- _____American Bittern-A
- _____Common Egret-O, A
- _____Snowy Egret-A
- _____Least Bittern-A

IBISES & FLAMINGOS
- _____Wood Ibis-A
- _____White-faced Ibis-A

SWANS, GEESE & DUCKS
- _____Whistling Swan-A
- _____Canada Goose-A, O
- _____Black Brant-Ac, A
- _____White-fronted Goose-A
- _____Snow Goose-A
- _____Ross' Goose-Ac, A
- _____Mallard-A
- _____Gadwall-A
- _____Pintail-A
- _____Green-winged Teal-A
- _____Blue-winged Teal-A
- _____Cinnamon Teal-A
- _____American Widgeon-A
- _____Shoveler-A
- _____Wood Duck-A
- _____Redhead-A
- _____Ring-necked Duck-A
- _____Canvasback-A
- _____Greater Scaup-A
- _____Lesser Scaup-A
- _____Common Goldeneye-Ac, A
- _____Barrow's Goldeneye-Ac, A
- _____White-winged Scoter-Ac,A
- _____Surf Scoter-Ac, A
- _____Bufflehead-A
- _____Ruddy Duck-A
- _____Common Merganser-A
- _____Red-breasted Merganser-A
- _____Hooded Merganser-A
- _____Fulvous Tree Duck-Ac, A

VULTURES
- _____Turkey Vulture-W

HAWKS, EAGLES & FALCONS
- _____Goshawk-G, W, R
- _____Sharp-shinned Hawk-G, W, R
- _____Cooper's Hawk-G, W, R
- _____Red-tailed Hawk-Wi
- _____Swainson's Hawk-O
- _____Rough Legged Hawk-Ac
- _____Ferruginous Hawk-O
- _____Red-shouldered Hawk-Ac,W,R
- _____Harris' Hawk-Ac
- _____Marsh Hawk-O, A
- _____Golden Eagle-O, Wi
- _____[Bald Eagle] -A
- _____Osprey -A
- _____[Prairie Falcon] -O
- _____[Peregrine Falcon] -O
- _____Pigeon Hawk-O, W
- _____Sparrow Hawk-O, R

GALLINACEOUS BIRDS
- _____Scaled Quail-O
- _____Gambel's Quail-O, R
- _____Mountain Quail-Ch, W
- _____Ring-necked Pheasant-*O
- _____White-winged Pheasant-*O
- _____Chukar-O,R,C
- _____Black Francolin *
- _____Gray Francolin *
- _____Crested Tinamous-*O
- _____Turkey-*W
- _____Sage Grouse-Sa

CRANES & RAILS
- _____Sandhill Crane-A, O
- _____Virginia Rail-A
- _____Sora Rail-A
- _____Common Gallinule-A
- _____Purple Gallinule-Ac, A
- _____American Coot-A, O

SHOREBIRDS
- _____Semi-palmated Plover-Ac, Sh
- _____Snowy Plover-Ac, Sh
- _____Golden Plover-Ac, Sh, O
- _____Upland Plover-O
- _____Killdeer-Sh, O, R
- _____Ruddy Turnstone-Ac, Sh
- _____Common Snipe-O, R, A
- _____Long-billed Curlew-Sh, O
- _____Whimbrel-Ac, Sh
- _____Spotted Sandpiper-Sh
- _____Willet-A, Sh
- _____Greater Yellowlegs-A, Sh
- _____Lesser Yellowlegs-A, Sh
- _____Pectoral Sandpiper-Ac, O, Sh
- _____Baird's Sandpiper-Sh, R
- _____Dunlin-Ac, Sh
- _____Least Sandpiper-A, Sh
- _____Long-billed Dowitcher-Sh
- _____Short-billed Dowitcher-Sh, A
- _____Stilt Sandpiper-A, Sh
- _____Western Sandpiper-A, Sh
- _____Marbled Godwit-Sh, O
- _____Sanderling-Ac, Sh
- _____American Avocet-A, Sh
- _____Black-necked Stilt-A, Sh
- _____Wilson's Phalarope-A, Sh
- _____Northern Phalarope-A

GULLS & TERNS
- _____Herring Gull-Sh, O, T, A
- _____California Gull-Sh, O, T, A
- _____Ring-billed Gull-Sh, O, T, A
- _____Bonaparte's Gull-A, Sh
- _____Forster's Tern-A, Sh
- _____Least Tern-Sh
- _____Caspian Tern-A
- _____Black Tern-A

PIGEONS & DOVES
- _____Band-tailed Pigeon-Ch, W
- _____White-winged Dove-O, G, R
- _____Mourning Dove-O, Wi
- _____Ground Dove-Ac
- _____Inca Dove-Ac
- _____Common Sand Grouse-*

CUCKOOS & ROADRUNNERS
- _____Yellow-billed Cuckoo-G, R
- _____Roadrunner-O

OWLS
- _____Barn Owl-O, G, W, C
- _____Screech Owl-W, R, G
- _____Flammulated Owl-Ac, W
- _____Great-horned Owl-W, Wi
- _____Snowy Owl-Ac, O
- _____Pygmy Owl-Ac, W
- _____Burrowing Owl-O
- _____Long-eared Owl-G, W, R
- _____Short-eared Owl-O
- _____Saw-whet Owl-G, W

GOATSUCKERS
- _____Whip-poor-will-Ac, W
- _____Poor-will-O, Ch, W
- _____Common Nighthawk-O, W, T
- _____Lesser Nighthawk-O

SWIFTS
- _____White-throated Swift-O, W, C
- _____Vaux's Swift-O, W

HUMMINGBIRDS
- _____Black-chinned Hummingbird-R,G,W
- _____Costa's Hummingbird-O, Sa, Ch
- _____Calliope Hummingbird-W, R
- _____Anna's Hummingbird-Ch, W
- _____Broad-tailed Hummingbird-R,Ch,W
- _____Rufous Hummingbird-R, W
- _____Allen's Hummingbird-Ac, R

KINGFISHERS
- _____Belted Kingfisher-A

WOODPECKERS
- _____Yellow-shafted Flicker-G, W
- _____Red-shafted Flicker-G, W
- _____Gila Woodpecker-O, G, R
- _____Acorn Woodpecker-Ac, W, G
- _____Lewis' Woodpecker-W
- _____Yellow-bellied Sapsucker-W, R
- _____Williamson's Sapsucker-W
- _____Downy Woodpecker-Ac, W, R, G
- _____Ladder-backed Woodpecker-O, G
- _____Hairy Woodpecker-W, R

FLYCATCHERS
- _____Eastern Kingbird-Ac, W, G
- _____Western Kingbird-O, R
- _____Cassin's Kingbird-Ac, O, W
- _____Scissor-tailed Flycatcher-Ac, O
- _____Ash-throated Flycatcher-W,Ch,O
- _____Wied's Crested Flycatcher-G,W,R
- _____Black Phoebe-R, C, T
- _____Say's Phoebe-O, C
- _____Least Flycatcher-Ac, W, G
- _____Traill's Flycatcher-R
- _____Hammond's-Dusky Flycatcher-W,R
- _____Gray Flycatcher-Sa, W, R
- _____Western Flycatcher-W, R
- _____Olive-sided Flycatcher-W, R
- _____Vermillion Flycatcher-R
- _____Western Wood Pewee-G, W

LARKS
- _____Horned Lark-O, Sa

SWALLOWS
- _____Violet-green Swallow-W, C
- _____Tree Swallow-A, R
- _____Bank Swallow-A
- _____Rough-winged Swallow-A, R
- _____Barn Swallow-A, O, T
- _____Cliff Swallow-R, C
- _____Purple Martin-W, R, T

JAYS, MAGPIES and CROWS
- _____Steller's Jay-W
- _____Scrub Jay-Ch, W
- _____Pinon Jay-W
- _____Black-billed M[illegible]e-Sa, G, R, T
- _____Common Ra[illegible]
- _____Common Cro[illegible]R, G
- _____Clark's Nutcracker-W

CHICKADEES & TITMICE
- _____Mountain Chickadee-W
- _____Plain Titmouse-G, W, R
- _____Verdin-Ch, R
- _____Common Bushtit-Ch, W

NUTHATCHES
- _____White-breasted Nuthatch-W, R
- _____Red-breasted Nuthatch-W
- _____Pygmy Nuthatch-W

CREEPERS
- _____Brown Creeper-W

DIPPERS
- _____Dipper (Water Ouzel)-A

WRENS
- _____House Wren-Ch, W, R, T
- _____Winter Wren-W, Ch
- _____Bewick's Wren-Ch, W, R
- _____Cactus Wren-O, Ch
- _____Long-billed Marsh Wren-A
- _____Canyon Wren-C
- _____Rock Wren-O, C

MOCKINGBIRDS & THRASHERS
- _____Mockingbird-Ch, R, T
- _____Catbird-Ac
- _____Brown Thrasher-Ac
- _____Bendire's Thrasher-O, G, W
- _____LeConte's Thrasher-O, R
- _____Crissal Thrasher-G, R
- _____Sage Thrasher-O, Sa, W, Ch

THRUSHES
- _____Robin-R, T
- _____Varied Thrush-Ac, W
- _____Hermit Thrush-W
- _____Swainson's Thrush-W, R
- _____Western Bluebird-O, W
- _____Mountain Bluebird-O, W
- _____Townsend's Solitaire-Ch, W
- _____Veery-Ac, G, W, R
- _____Wood Thrush-Ac

GNATCATCHERS & KINGLETS
- _____Blue-gray Gnatcatcher-Ch,G,W,R
- _____Black-tailed Gnatcatcher-O,G,Sa,R
- _____Golden-crowned Kinglet-Ac, W
- _____Ruby-crowned Kinglet-G,R,W

PIPITS
- _____Water Pipit-Sh, O

WAXWINGS
- _____Bohemian Waxwing-G,R,W
- _____Cedar Waxwing-G, R, W

SILKY FLYCATCHERS
- _____Phainopepla-O, G

SHRIKES
- _____Northern Shrike-Ac, O
- _____Loggerhead Shrike-O

STARLINGS
- _____Starling-O, G, T

VIREOS
- _____Bell's Vireo-G, R
- _____Gray Vireo-Ch, W
- _____Solitary Vireo-W
- _____Warbling Vireo-W
- _____Yellow Throated Vireo-Ac
- _____Hutton's Vireo-Ac, W, Ch

WARBLERS
- _____Black and White Warbler-Ac, W
- _____Orange-crowned Warbler-O, Ch,W
- _____Virginia's Warbler-Ch, G, W, R
- _____Tennessee Warbler-Ac, G, W
- _____Lucy's Warbler-R, G
- _____Yellow Warbler-R, G, T
- _____Myrtle Warbler-G, W, R
- _____Audubon's Warbler-G, W, R
- _____Black-throated Gray Warbler-G,W,R
- _____Townsend Warbler-W
- _____Black-throated Green Warbler-Ac,W
- _____Black-poll Warbler-Ac, W
- _____Hermit Warbler-W
- _____Grace's Warbler-Ac, W
- _____Ovenbird-Ac, W, G

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